OBSERVATIONS OF LAKE TROUT *(SALVELINUS NAMAYCUSH)* SPAWNING BEHAVIOUR IN LOW pH LAKES NEAR SUDBURY, ONTARIO

ONTARIO FISHERIES ACIDIFICATION REPORT SERIES NO. 87-10

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ABSTRACT

The spawning behaviour of lake trout (*Salvelinus namaycush*) was assessed in 5 low pH (pH 5.1 - 5.7) lakes in the Sudbury area and in one circumneutral reference lake. The lake trout in the low pH lakes exhibited recruitment failure with no evidence of successful reproduction for, in some cases, a decade or more. The numbers of native lake trout in the low pH lakes were estimated to be in the range from 2 to 22. The remnant adult populations continued to spawn and produce viable gametes. Selected spawning sites were shallow (6 cm - 3 m depth) and usually near shore, making them vulnerable to acidic run-off. Some sites were located well offshore (~ 75 m) with little potential of exposure to run-off water.

Extensive use was made of ultrasonic transmitter tags to locate spawning sites and to provide information about the movements of adults during the spawning period. Additional findings included: egg predation by juvenile hatchery-stocked lake trout, unusual inverted swimming displays by spawning adults, and spawning of mature hatchery-stocked lake trout with native adults.

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1. INTRODUCTION

As lakes acidify, fish populations generally decline through recruitment failure, i.e., failure to spawn (Beamish 1976, Johnson and Webster 1977) or mortality during early life history stages (Schofield 1976, Muniz and Leivestad 1980, Haines 1981). Mass mortality of juveniles or adults has been occasionally observed (Jensen and Snekvik 1972, Leivestad and Muniz 1976). In long-lived species such as lake trout (*Salvelinus namaycush*), acid stressed populations can be composed of only a few adults which survive for a decade or more after recruitment has ceased. Several such populations exist in the acidic lakes near Sudbury, Ontario (Beamish and Harvey 1972, Beggs et al. 1985). Recruitment failure in lake trout appears to begin when lake pH drops below 5.5 - 5.6 (Beggs et al. 1985, Beggs and Gunn 1986).

This paper describes lake trout spawning assessments conducted by staff of the Ontario Ministry of Natural Resources (OMNR) during the period 1983 to 1985 on four low pH lakes near Sudbury - Whitepine Lake (pH 5.7), Laundrie Lake (pH 5.36), Michaud Lake (pH 5.45) and Marina Lake (pH 5.13) (Fig. 1.0). In each of these lakes, the lake trout populations consisted of a few large non-recruiting adults. A reference lake, Lake Panache (pH 6.38), with a healthy reproducing population was also included in the study. Physical and chemical characteristics of the study lakes are listed in Table 1.1.

The sections that follow provide detailed descriptions of brood stock status, lake trout spawning behaviour, and spawning sites for each of the above lakes. Extensive use was made of ultrasonic transmitter tags to monitor fish movements. Ultrasonic tracking procedures are described in Appendix 1.

Table 1.1 Physical and chemical characteristics of study lakes.

	Whitepine	Laundrie	Michaud	Marina	Panache
North latitude	47°17'	47°07'	46°49'	47°24'	46°15'
West longitude	80°50'	80°52'	81°18'	80°40'	81°20'
Surface area (ha)	67	374	148	37	7,735
Maximum depth (m)	22	20	24	17	56
Mean depth (m)	5.9	4.9	7.0	4.6	14.7
pH	5.7	5.4	5.45	5.13	6.4
Conductivity (uS/cm)	35	35	33	38	64
Alkalinity (mg/l as $CaCO_3$)	0.29	0.03	0.13	-0.25	4.1

2. WHITEPINE LAKE (pH 5.7) - 1983

A 1978 aquatic habitat inventory survey on Whitepine Lake captured nine large native lake trout, with fork lengths from 55.8 to 60.5 cm and age approximately 15 years, 262 yellow perch (*Perca flavescens*) and a few unidentified cyprinids (OMNR Sudbury District file report). Later in 1980 and 1981, ling (*Lota lota*) and common white sucker (*Catostomus commersoni*) were added to the species list (J. Gunn, unpublished data). The latter two species were extremely scarce and the catch consisted only of large mature fish, indicating that recruitment failure was occurring in these species as well as in lake trout.

During the period of the spawning assessment, Whitepine Lake also contained some stocked fish. In fall of 1980 the lake had been stocked with 800 adipose-fin-clipped yearling lake trout from Tarentorus Hatchery located in Sault Ste. Marie, Ontario. In the spring of 1981 it was again stocked with 800 fish from the same lot (now age 2+). In the fall of 1982, 16 adult lake trout were also transferred to Whitepine Lake from nearby Regan Lake, a lake which supported a healthy reproducing lake trout population.

This spawning assessment was conducted to determine: (1) where lake trout spawned, (2) if fish from the three different origins spawned together, and (3) to characterize the spawning site(s) and the distribution of eggs within substrates.

METHODS

Spawning observations on Whitepine Lake were carried out during October 15 - November 1, 1983. Visual inspections of shoreline areas with rock rubble substrate, areas considered suitable for lake trout spawning (Martin and Olver 1980), were made every second night with the aid of 12 volt tractor headlights.

Single panels of gillnet with mesh size ranging from 2.54 to 5.08 cm were set briefly (10 min.) along shorelines to capture adults. Captured fish were anesthetized with MS 222, measured, examined for state of maturity and tagged with yellow disc streamer tags. Three fish were tagged with ultrasonic transmitter tags.

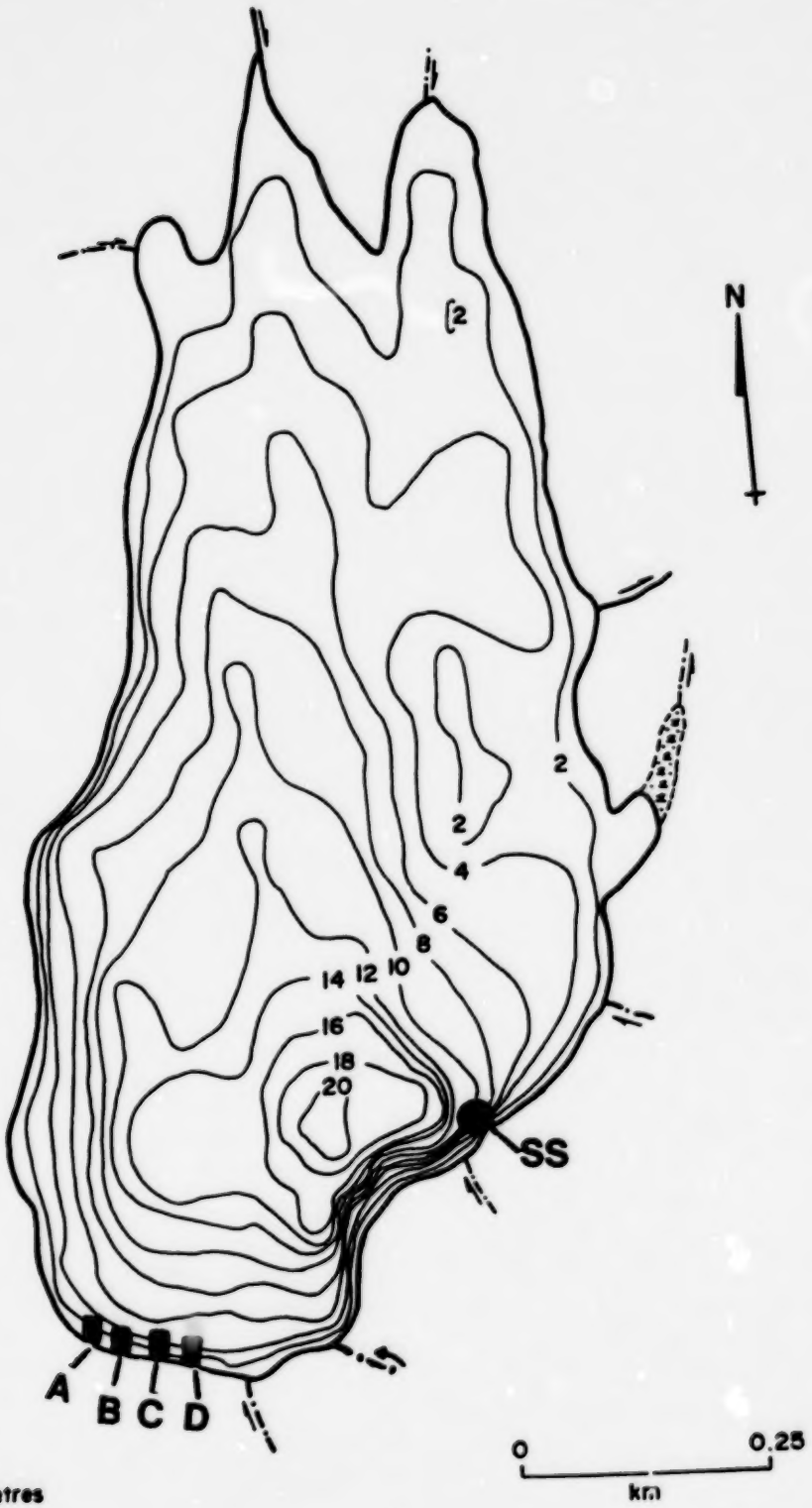
RESULTS

Spawning Population

Visual observations and gillnet captures on October 15th and 16th indicated that mature lake trout were concentrated along the southern shore with a few found along the eastern shore near the previously documented spawning site SS (Fig. 2.1). After October 16th, activity was restricted to sites along the southern shore.

The spawning population of lake trout in Whitepine Lake consisted of fish from all three stocks. In total, 7 natives, 5 Regan transplants and 25 stocked fish were caught and tagged (Appendices 2 and 3). Only 4 out of 37 captured fish were females. No mature females were found in a sample of 25 stocked fish (age 4+); 21 of these were mature males.

Figure 2.1 Depth contours of Whitepine Lake and location of lake trout spawning sites (A, B, C, D, and SS).



From October 19th until the peak of activity around October 24th, there was a steady increase in the number of lake trout milling over the beds along the south shore (A, B, C, D). Numerous observations were made of fish apparently cleaning beds by wriggling against the bottom, turning on their sides, arching their bodies downward, and alternately digging into the substrate with their snouts and tails. At site D, lake trout moved fist-size rocks and excavated depressions (0.3 m in diameter and 0.10 to 0.15 m deep) in the gravel.

Mating and courtship behaviour were displayed in the form of mutual prodding and nudging. Near the time of peak activity (8.4^{o}C water temperature), an estimated 60 to 90 per cent of the fish were sporting yellow streamer tags. On many occasions during daylight hours, lake trout were observed rolling singly and in pairs at the surface near the sites.

The physical act of spawning was never directly observed, but eggs were discovered at sites A, B, C, and D on the afternoon of October 24th. From the surface, approximately 20 eggs in total were counted at the four sites. More spawning occurred on the night of October 24th, with 70 or more eggs observed the next day. No obvious increase in egg numbers occurred after October 26th.

Post-spawning behaviour was marked by a gradual decrease in activity. Fish roamed, singly or in small groups, over and near the beds, both during daylight and in the evenings. Three spent males were captured on October 30th: two of hatchery origin and one Regan transplant.

Ultrasonic Tracking

Three fish received sonic tags: a native male (A) on October 16th, a Regan female (B) on October 17th and a second Regan female (C) on October 23rd (Table 2.1).

TABLE 2.1 Sonic tagged lake trout in Whitepine Lake - 1983

Fish ID	Date Caught	Site Caught	Sex	Origin	Frequency (khz)	Pulse Rate (beats/min.)
A	Oct 16	2	Male	Native	69.00	50
B	Oct 17	2	Female	Regan	76.80	60
C	Oct 23	2	Female	Regan	65.54	60

See Fig. 2.1 for site locations

Movements for tagged fish are illustrated in Figs. 2.2, 2.3, and 2.4. After release, all fish remained stationary for up to 24 hours. Some evidence of sex differences in behaviour became evident after fish began moving. Except for a brief excursion to the northeast shore shortly after tagging, the male remained in the proximity of the spawning beds at the south shore. In contrast, the females ranged widely, only converging on the beds during the peak of spawning activity (October 24 - 26, 1983).

All sonic tagged fish appeared healthy when observed swimming over the beds on October 24th.

Spawning Sites

Lake trout spawned at four sites, A, B, C, and D, (Table 2.2) at the south end of the lake along a 100 m stretch of shoreline. All sites were shallow (<1.5 m) and less than 5 m from shore. The shoreline consisted of large rocks and boulders (50 to 100 cm in

Figure 2.2 Movements of sonic tagged male lake trout (fish A) in Whitepine Lake, October 16 - 31, 1983. The location of spawning sites (A, B, C, D, and SS) are indicated.

Position	Date	Time
1	Oct. 16	1200 released
2	" "	1230 - 2100
3	" "	2115
4	" "	2230
2*	Oct. 17	0900 - 1300
2*	Oct. 18	1600
5	" "	1900 - 2400
2*	Oct. 19	0930
5*	Oct. 22	1530 - 2400
2*	Oct. 23	1030
5*	Oct. 24	1600 - 2200
5*	Oct. 25	1000 - 1100
2*	Oct. 26	1600
5*	" "	1945
2*	Oct. 27	1000
5*	Oct. 30	1400 - 2030
6	" "	2030
2*	Oct. 31	0900 - 1430

Lines with arrows connect fish positions at specific times and do not necessarily indicate actual path of travel.

* - located at same position on more than one occasion

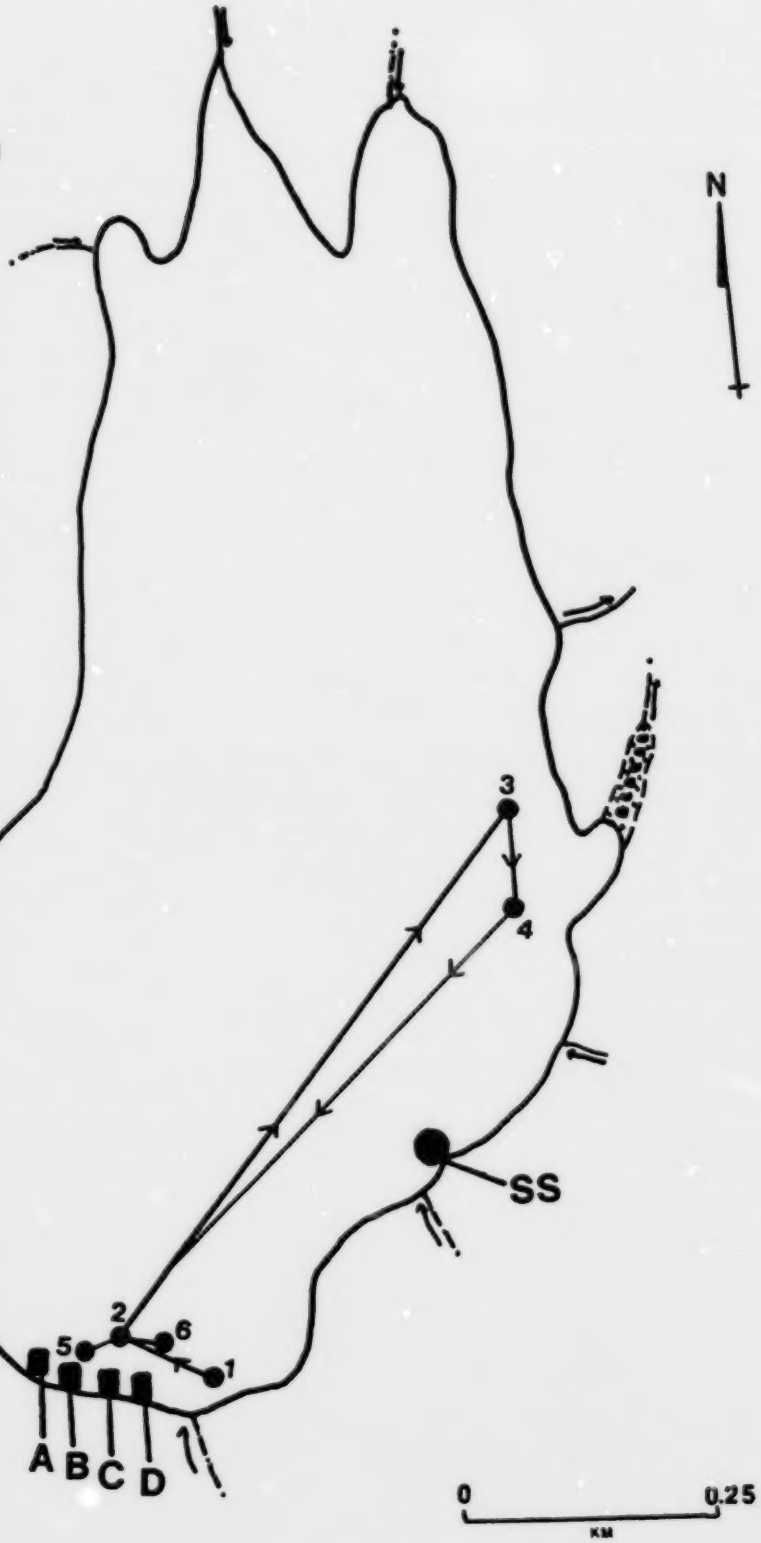


Figure 2.3 Movements of sonic tagged female lake trout (fish B) in Whitepine Lake, October 17 - 31, 1983.

Position	Date	Time
1	Oct. 17	0900 released
2	* *	0910 - 1300
3	Oct. 18	1400 - 2400
4	Oct. 19	0930
5	Oct. 22	1530 - 2300
6	* *	2300 - 2400
7	Oct. 23	1030
5*	Oct. 24	1600
4*	* *	1900 - 2000
5*	Oct. 25	1000
5*	Oct. 26	1600 - 2315
8	Oct. 27	1000
9	Oct. 30	1400
10	* *	1830 - 2100
11	Oct. 31	0900 - 1430

Lines with arrows connect fish positions at specific times and do not necessarily indicate actual path of travel.

* - located at same position on more than one occasion

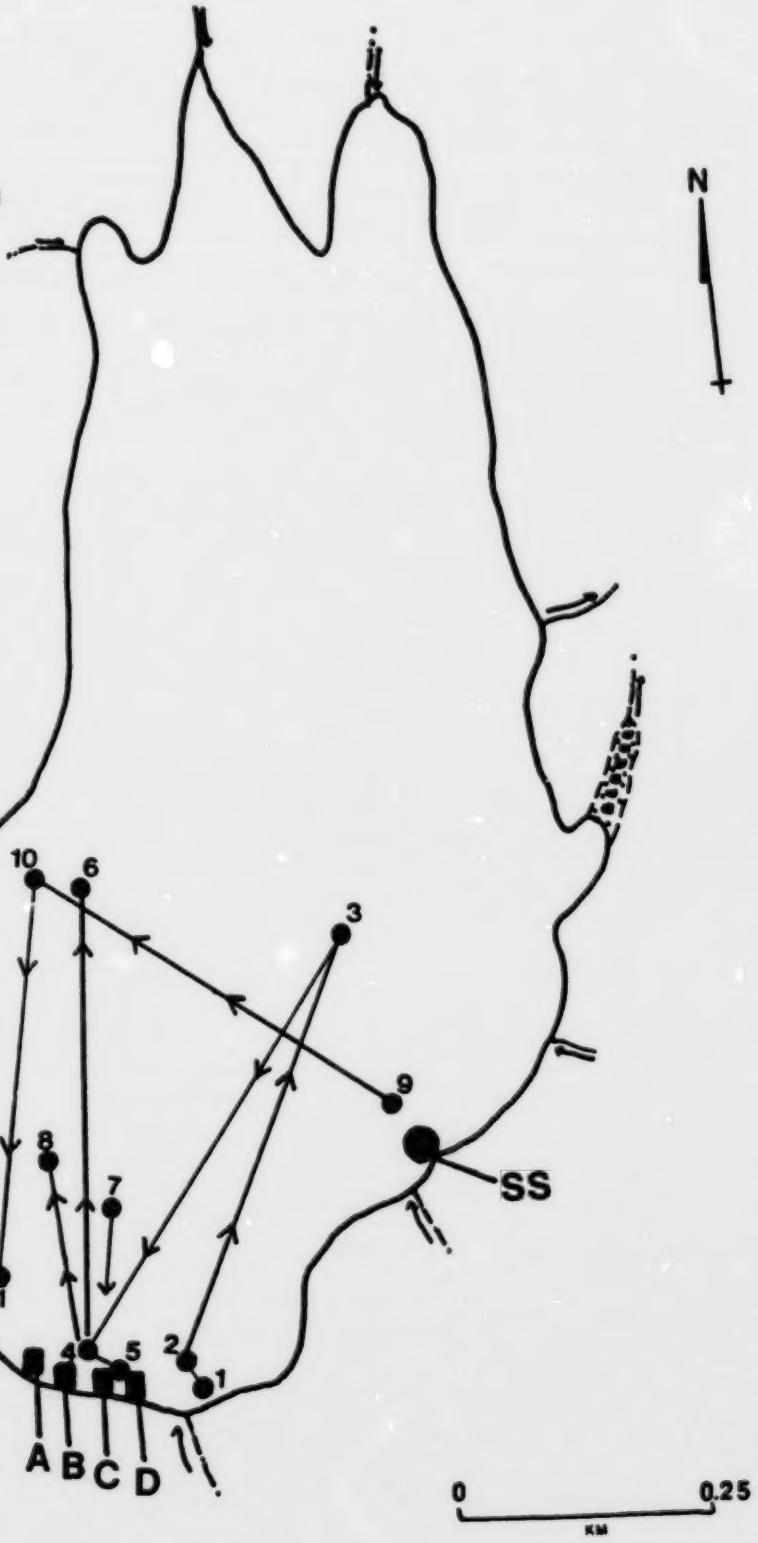


Figure 2.4 Movements of sonic tagged female lake trout (fish C) in Whitepine Lake, October 23 - 31, 1983.

Position	Date	Time
1	Oct. 17	0900 released
2	" "	0910 - 1300
3	Oct. 18	1400 - 2400
4	Oct. 19	0930
5	Oct. 22	1530 - 2300
6	" "	2300 - 2400
1*	Oct. 23	1030
2*	Oct. 24	1710
3*	" "	1900 - 2000
2*	Oct. 25	1000 - 1100
2*	Oct. 26	1600
3*	" "	1945
4*	" "	2000 - 2315
5*	Oct. 27	1000
6*	Oct. 30	1400
2*	" "	1830
7	" "	2030
8	Oct. 31	0900 - 1430

Lines with arrows connect fish positions at specific times and do not necessarily indicate actual path of travel.

* - located at same position on more than one occasion

diameter). The bottom substrate consisted of coarse gravel mixed with rock 5 to 20 cm in diameter.

Table 2.2 Physical features of lake trout spawning sites on Whitepine Lake - October, 1983.

Site	Min Depth (cm)	Max Depth (cm)	Cleared Area (m^2)	Remarks
A	40	47	4.0	--
B	40	46	2.0	--
C	40	52	2.0	Well cleaned
D	100	150	15.0	Well cleaned
SS	70	100	6.0	Not used in 1983

See Fig. 2.1 for site locations

Once spawning was finished, inspection of the spawning beds by a diver revealed that eggs were generally found at a depth of 10 cm from the top of the substrate ranging down to 20 cm. This distribution of eggs was determined by viewing from a lateral angle while carefully lifting rocks. The eggs appeared to be in good condition, coloured orange-yellow with no obvious white spots. Very few white (unfertilized or dead) eggs were found.

No egg deposition occurred at the spawning site (SS) used in 1982. (Note: In the fall of 1985, fish were again using site SS (J. M. Gunn, unpublished data).

3. LAUNDRIE LAKE (pH 5.4) - 1983

Extensive netting surveys, conducted between 1976 and 1979, indicated that the fish community in Laundrie Lake consisted of a few large adults of each of the following species: lake trout, longnose sucker (*Catostomus catostomus*), and common white sucker (*Catostomus commersoni*). Yellow perch, an acid-tolerant species, was present in large numbers. A preliminary investigation conducted in the fall of 1979 (Gunn 1980) verified that native lake trout still produce eggs and milt but no spawning sites were identified.

In an effort to re-establish a naturally reproducing population, Laundrie Lake was stocked four times with hatchery-reared lake trout: 8000 fingerlings (unmarked) in 1977, 4000 yearlings (adipose-fin-clipped) in 1980, 3000 fingerlings (unmarked) in 1981 and 1500 (adipose-fin-clipped) yearlings in 1983.

A spawning assessment was conducted on Laundrie Lake from October 17 - November 1, 1983. The objectives of the study were:

1) to determine if native or stocked fish spawned
2) to locate and describe spawning sites.
3) to describe the distribution of eggs within the substrate.

METHODS

The spawning assessment on Laundrie Lake ran concurrently with the study on Whitepine Lake and observations were conducted on each lake on alternate evenings starting October 17th. Field observations were concentrated in the southern basin of Laundrie Lake where previous netting surveys indicated that lake trout

were most abundant (J. M. Gunn, unpublished data).

RESULTS

Status of Spawning Population

Seven lake trout were captured: three natives (this distinction based on size), two 1980 stocked fish, and two unclipped fish (#260052 and #260053) which were either smaller natives or 1977 stocked fish (Table 3.1). Only one gravid native female was caught. In addition to the fish captured in gillnets, a few others (approx. 4 to 6) were seen at sites D and E (Fig. 3.1).

TABLE 3.1 Lake trout tagged[1] during fall spawning on Laundrie Lake - 1983.

Tag #	Date Caught	Site Caught	Fork Length (cm)	Total Length (cm)	Sex	Clip[2]	Origin[3]	Remarks
260050	Oct.17	A	49.4	53.5	Male	AD	S77	Sonic tag 'A'
260051	Oct.23	E	63.0	68.5	Male	NC	native	
260052	"	A	57.8	63.5	Male	NC	native or S77	
260053	"	E	53.7	58.8	Male	NC	native or S77	
260054	"	D	67.2	73.3	Male	NC	native	Sonic tag 'B'
260055	Oct.25	D	53.4	58.4	Male	RP	S80	
260056	"	D	60.0	65.9	Female	NC	native	Sonic tag 'C'

(1) Yellow streamer tags
(2) AD - Adipose, NC - No clip, RP - Right pectoral
(3) S80 - stocked in 1980, S77 - stocked in 1977

Spawning Observations

A mature male (1977 stocked origin) (Table 3.1) was caught off point A in the southern basin on October 17th (Fig. 3.1) and the following morning received sonic tag 'A'. Two days later, on October 19th, the tagged male had moved into the eastern end of the shallow bay in the southern basin. Inspections of near-shore

Figure 3.1 Depth contours of Laundrie Lake and locations of shoreline sites where lake trout were observed (A - E). Spawning occurred at Site C.

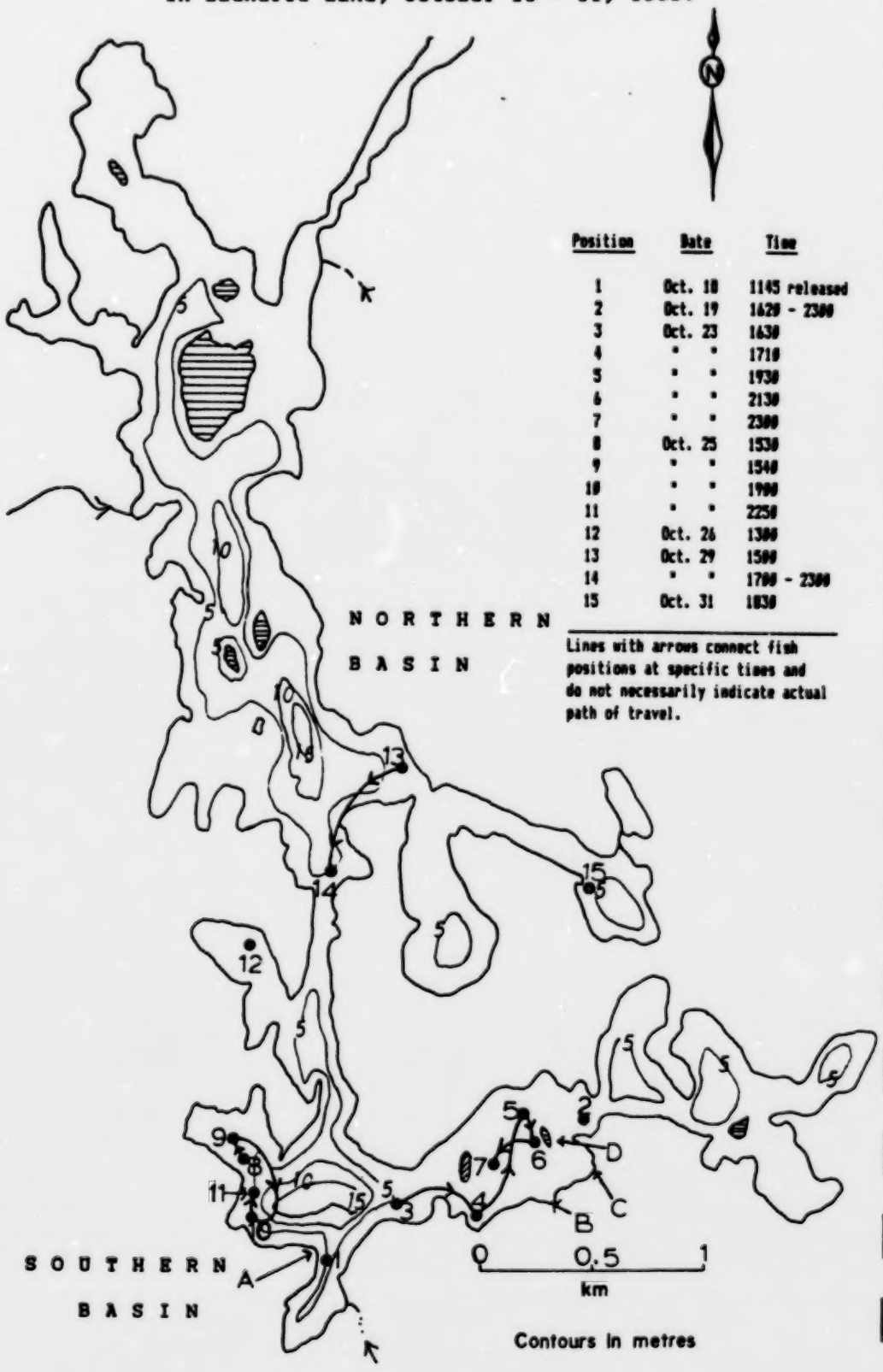
areas in the vicinity failed to locate any other fish or evidence of activity (e.g., cleared areas). On October 23rd, fish were found along the windswept shore of a small island at sites D and E (Fig. 3.1). Two native males and another 1977 stocked lake trout were captured and tagged. One of the native males received sonic tag B. A large gravid female - presumably a native - escaped during handling.

Oviposition was discovered at site C on October 25th by tracking a sonic tagged native male (B). The following morning 20 eggs were observed at site C. None were found at site B where the spawning pair was first encountered. Continued inspections of shorelines on the night of October 25th and tracking of males and a single female failed to produce any other sites.

Ultrasonic tracking

Three fish received ultrasonic transmitter tags (Table 3.2): a 1980 stocked male - tag 'A', a native male - tag 'B', and a native female - tag 'C'. Fish movements are illustrated in Figs. 3.2, 3.3, and 3.4, respectively. Stocked male 'A' wandered through both basins (Fig. 3.2) and was not found near any sites suitable for spawning. In contrast, the movements of native male 'B' were restricted to a small area bounded by sites B, C, D, and E (Figure 3.3). Native female 'C' was tagged late in the season and her movements were restricted to a small area of the south basin (Fig. 3.4).

Figure 3.2 Movements of sonic tagged male lake trout (fish A) in Laundrie Lake, October 18 - 31, 1983.



Position	Date	Time
1	Oct. 18	1145 released
2	Oct. 19	1620 - 2300
3	Oct. 23	1630
4	" "	1710
5	" "	1930
6	" "	2130
7	" "	2300
8	Oct. 25	1530
9	" "	1540
10	" "	1900
11	" "	2250
12	Oct. 26	1300
13	Oct. 29	1500
14	" "	1700 - 2300
15	Oct. 31	1830

Lines with arrows connect fish positions at specific times and do not necessarily indicate actual path of travel.

Figure 3.3 Movements of sonic tagged male lake trout (fish B) in Laundrie Lake, October 24 - 3, 1983.

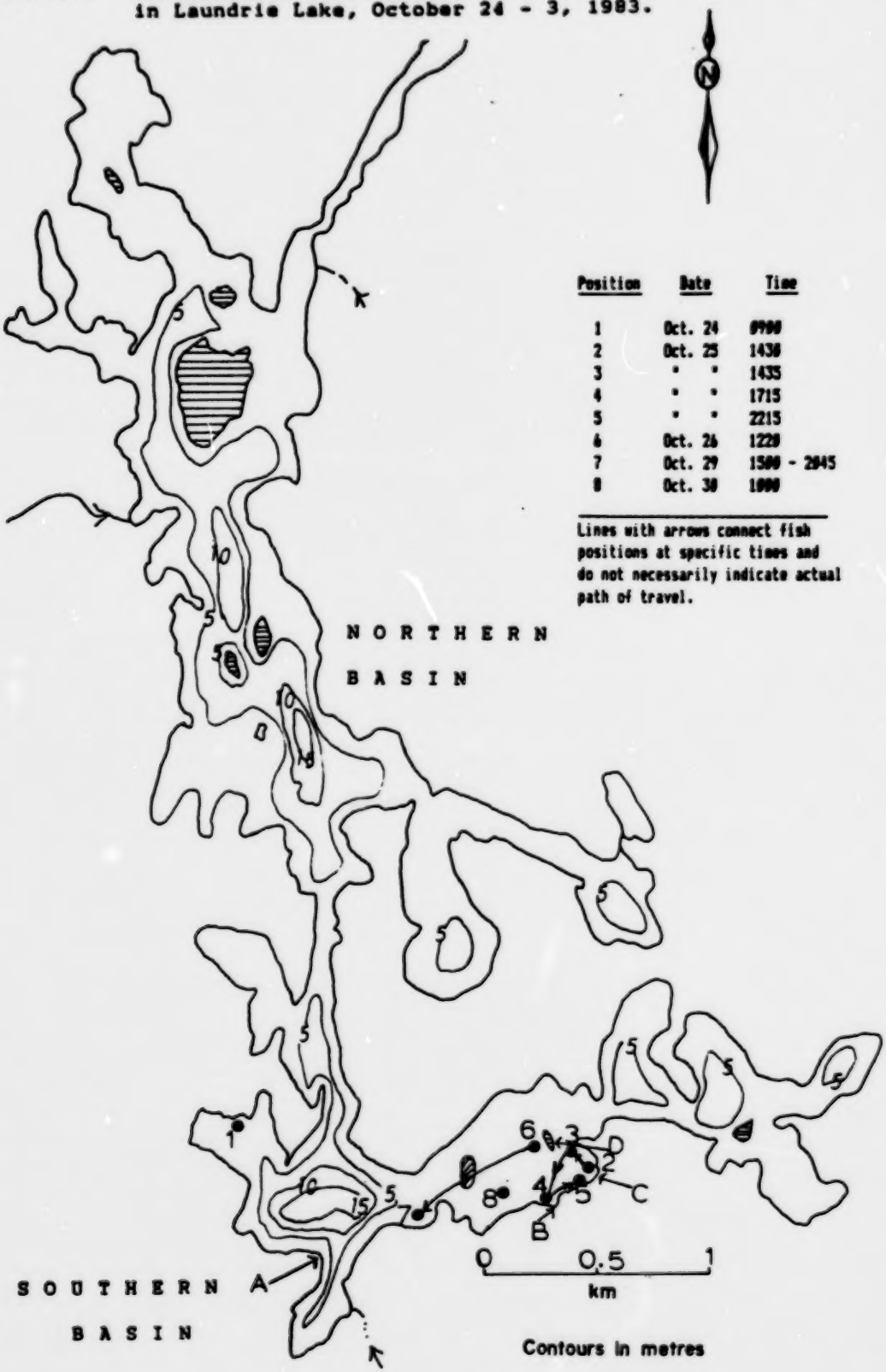


Figure 3.4 Movements of sonic tagged female lake trout (fish C) in Laundrie Lake, October 26 - November 1, 1983.

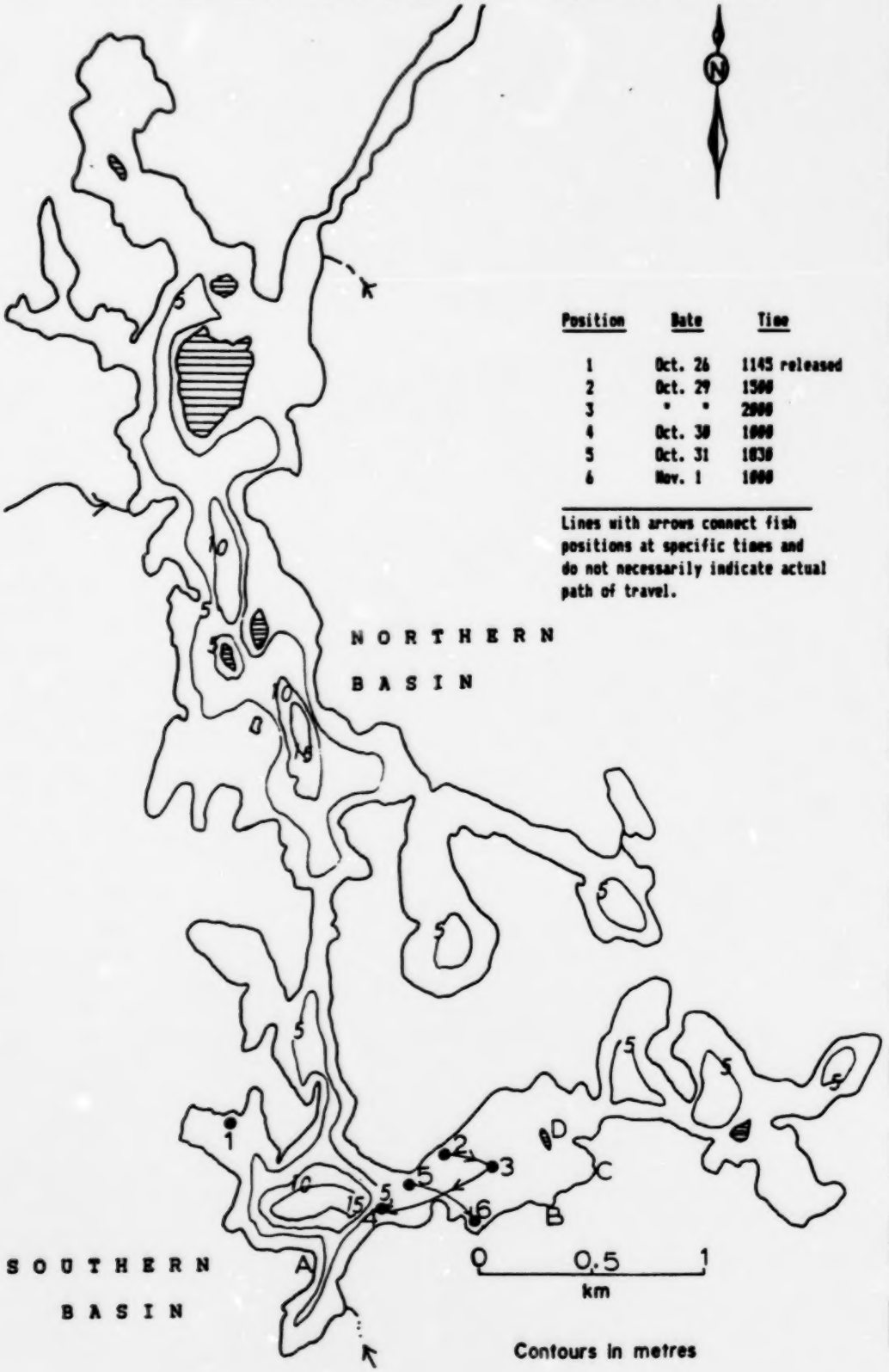


TABLE 3.2 Sonic tagged lake trout on Laundrie Lake - 1983.

Fish ID	Date Caught	Site Caught(1)	Sex	Origin	Frequency (khz)	Pulse Rate (beats/min.)
A	Oct.17	A	Male	Stocked 1977	65.54	50
B	Oct.23	D	Male	Native	74.00	68
C	Oct.25	D	Female	Native	69.00	60

(1) See Fig. 3.1 for site locations

Spawning Site

Site C, the confirmed spawning site, was small in area (0.8 m^2) and situated 1 m offshore in only 18 cm of water. Distribution of eggs within the substrate was also shallow. The original count of 20 eggs was increased to approximately 50 by searching through the gravel. When oviposition was first confirmed at the site on October 26th, water temperature was 6.4^{o}C and dissolved oxygen was 11.0 ppm. The eggs deposited appeared to be quite whitish perhaps indicating low fertilization success. The rock rubble at the site was small (2 to 5 cm in diameter), free of silt and detritus and exposed to the northwesterly winds which prevail in the fall.

Table 3.3 Physical features of spawning site and other sites of activity on Laundrie Lake - 1983.

Site	Depth		Area (m^2)	Remarks
	Minimum	Maximum		
B	18	18	0.5	Some clearing
C	18	18	0.8	No clearing, clean uniform rubble
D	22	78	0.4	Obvious clearing
E	15	22	0.4	Poorly cleared

Note: See Figure 3.1 for site locations

The other sites (Table 3.2) where fish were observed (B, D, and E) had limited areas of suitable substrate. At sites D and E, small pockets of 10 cm diameter rubble were found on rock ledges next to shore in areas of steep drops into deep water. At site B, a small area of rubble was interspersed with large rocks and boulders along the shoreline.

4. MICHAUD LAKE (pH 5.45) - 1984

In 1980 an aquatic habitat inventory survey of Michaud Lake reported a catch of 5 large lake trout (FL 48.9 to 59.5 cm) and numerous yellow perch (OMNR, Sudbury District file report). Subsequent effort with small mesh gillnets (1.3, 1.7 and 2.5 cm stretched mesh monofilament) in 1981, 1982 and 1983 failed to capture any younger year classes of lake trout. Five adults caught in 1982 were assigned ages from 20 to 29 years by examining otoliths (OMNR 1983a).

In May of 1984, the lake was stocked with 1800 fin-clipped (adipose) hatchery-reared yearling (age 1+) lake trout and in October of the same year 12 marked adults (6 of each sex) were transplanted from Lake Panache.

This section describes (1) a lake trout spawning assessment conducted on Michaud Lake in October 1984 and (2) a preliminary experiment to test the viability of gametes produced by native spawners.

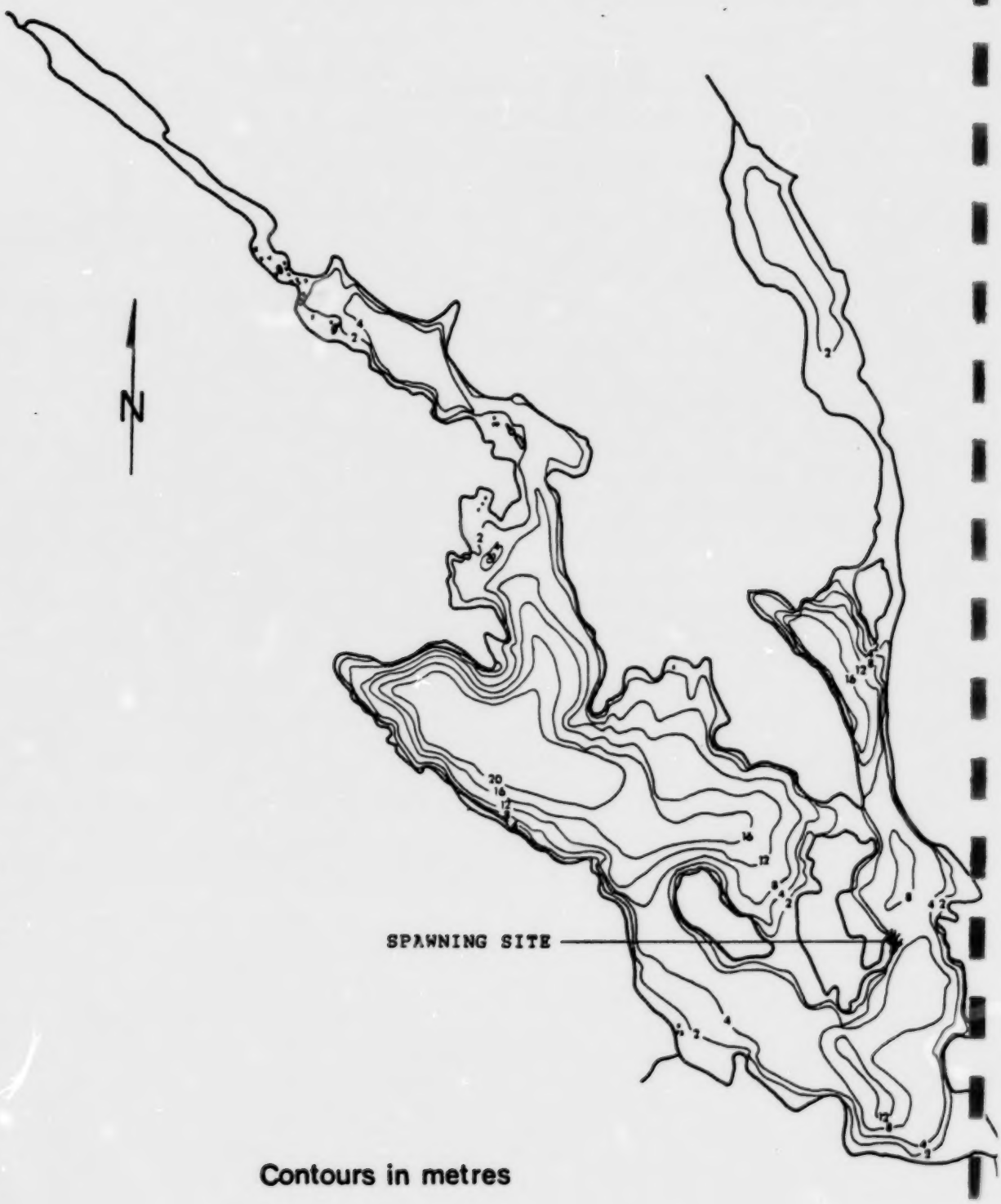
METHODS

Spawning Observations

A preliminary search for lake trout and spawning sites was conducted from October 10th to 12th, between twilight (1900 h) and midnight (2400 h). When weather conditions allowed, inspections continued during daylight hours.

Once a spawning site was found (Fig. 4.1), nightly observations at the site continued until a marked decline in spawning activity was evident. Viewing was done both from shore and from a boat with illumination provided by shaded flashlights.

Figure 4.1 Morphometric map of Michaud Lake showing depth contours (m) and location of lake trout spawning site.



Temperature and dissolved oxygen were recorded daily at the spawning site (Appendix 4(a)) and on alternate days, temperature and dissolved oxygen profiles (at 1 m depth intervals) were recorded in the mid-lake basin (Appendix 4(b)).

Ultrasonic Tracking

Captured fish were held overnight in mesh retainers and tagged with sonic tags the following morning. Fish were released at the site of capture and their positions then plotted at 2 to 4 h intervals during the day and more often in the evening until midnight. Whenever fish were found near shore, substrates in the vicinity were inspected for any evidence of cleaning activity, oviposition or the presence of other fish.

Test of Gamete Viability

On October 14th, gametes from native spawners were dry stripped and mixed to provide fertilized eggs to test viability of progeny. Eggs were loaded into incubator trays marked to distinguish parental origin and were then set on rock substrate at the spawning site in 0.9 m of water. A Ryan Model "J" continuous recording thermograph was set beside the trays.

The two incubator trays were constructed of white plastic "egg crating" (1 cm square holes). Three 0.2 m^2 pieces of crating were stacked together with intervening layers of plastic window screening to form an incubator. Eggs were placed in the centre layer (~ 3 - 4 eggs per hole) and the incubators were held together by elastic bands.

On January 22nd, 1985, the incubator trays were retrieved and live eggs and free embryos counted. Dissolved oxygen and temperature were recorded at the site and water samples, taken adjacent to the incubators, were submitted to Ministry of Environment for analysis of pH and alkalinity.

RESULTS

Status of Spawning Population

In total, nineteen native spawners were captured at 3 sites and of these 6 were confirmed males and 3 were confirmed females (Table 4.1). Nine fin-clipped yearlings of hatchery origin were also caught at Sites A, D, and SS (Fig. 4.2). For natives (males and females combined), mean fork length was 57.5 ± 2.4 cm (n = 11) and mean weight was 2537 ± 490 g (n = 10) (Table 4.1). The mean fork length and mean weight for stocked fish (n = 9) were 21.0 ± 1.8 cm and 101 ± 34 g, respectively.

Spawning Observations

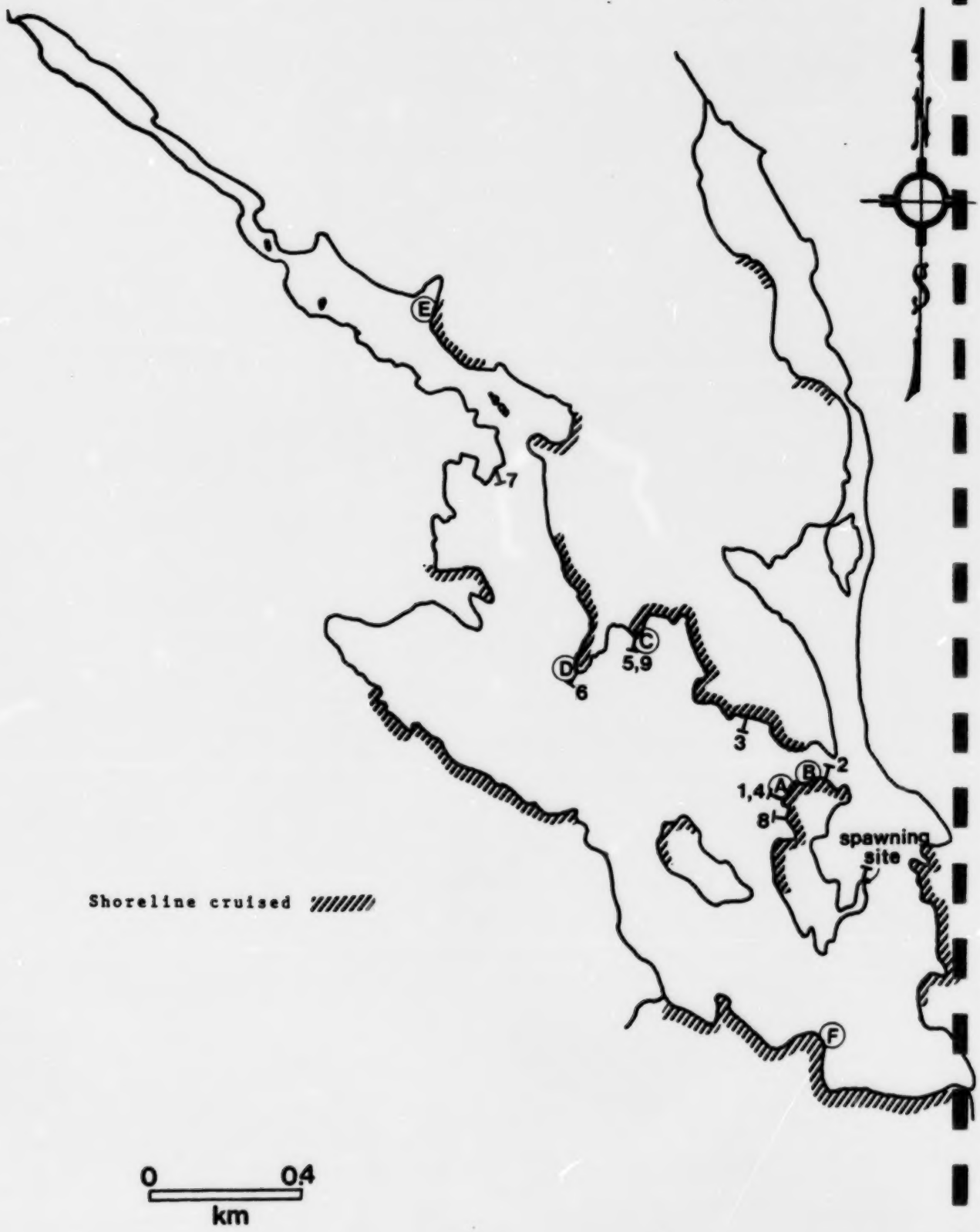
During the period October 10 - 12, 1984, five native lake trout were captured in gillnets set along shorelines. Three were caught at Site A and two at Site C (Table 4.1 and Fig. 4.2) - all received ultrasonic transmitter tags. Three other natives were observed at Sites A and B but none were captured. Males released milt readily while females released eggs only while under the influence of anesthetic. No evidence of substrate cleaning or oviposition were found at sites A, B, C, or D and after October 12th no further sightings of natives were recorded at any of these sites.

Table 4.1. Summary of lake trout captured during spawning on Michaud Lake - October, 1984.

Date Caught	Site[1]	Length (cm) Total	Fork	Weight (g)	Sex	Tag #	Comments
		NATIVES (n = 11)[2]					
10	A	62.1	56.3	2040	U	B55801[3]	Sonic tag 129
11	"	64.4	59.2	2700	U	B55804[3]	AD clip[4], Sonic tag 112[5]
"	"	65.5	59.1	2520	F	B55805[3]	AD clip[4], Sonic tag 111[5]
"	C	52.5	50.6	1500	M	B55806[3]	Sonic tag 130
12	"	65.3	59.0	3359	F	B55809	Sonic tag 5246
13	SS	64.0	59.0	2750	M	B55810[5]	
"	"	66.8	61.0	2340	M	B55811[5]	
"	"	63.3	57.8	2520	M	B55812[5]	
"	"	62.5	57.7	2560	F	B55813[5]	
16	"	62.3	56.8	3000	M	B55814	
"	"	60.7	54.5	--	M	B55815	
	x(±SD)	63.1(2.6)	57.5(2.4)	2537(490)			
		STOCKED (n = 9)					
10	A	21.0	19.6	61	U	B55800	
11	"	22.0	20.1	95	U	B55802	Ad. clip
"	"	25.5	23.2	140	U	B55803	Ad. clip
"	"	24.7	22.6	150	F (ima)	--	Ad. clip Died in net
"	D	22.6	19.7	83	M (ima)	--	Ad. clip
12	"	20.9	19.2	71	U	B55807	Ad. clip
"	"	24.0	21.9	100	U	B55808	Ad. clip
16	SS	25.5	22.4	--	U	--	Ad. clip
"	"	22.0	20.0	--	U	--	Ad. clip
	x(±SD)	23.1(1.8)	21.0(1.5)	101(43)			

(1) See Figure 4.2 for netting sites.
(2) An additional 8 natives were caught on October 13th - no data was recorded.
(3) Recaptured October 13th
(4) Adipose fin was removed during previous netting assessment
(5) Contributed eggs or milt to gamete viability test
Note: Natives were fin-clipped (adipose) prior to release.

Figure 4.2 Gillnetting sites (numbered) and potential lake trout spawning sites (lettered) - Michaud Lake, October 1984



On October 13th, 11 males and 2 females were captured at the spawning site and, of these, 3 males and 1 female were tagged with yellow streamer tags (Table 4.1). Males and females both readily released gametes. After October 13th, activity at the site declined; on October 16th, two ripe males were captured and by October 17th only 4 fish were seen (Table 4.2).

Table 4.2 Estimated total number of spawning lake trout observed at the spawning site and ratio of males to females for gillnet captures - Michaud Lake, October 13 - 17,1984.

Date	Total No.(1)	Description of fish			Sex ratio (male:female)(2)
		Disc Tags	Sonic Tag #	Unmarked	
13	13	--	111(F)(3) 112(U)	11	5:1
14	6	1	5246(F)	4	--
15	6	3	5246(F)	2	2:1
16	6	4	5246(F)	1	2:1
17	4	1	5246(F)	2	--

(1) Highest single count of natives
(2) Sex ratio determined from gillnet captures
(3) (F) - Female (U) - unknown sex

Fish moved onto the spawning site around 1830 h and left around 2300 h. Spawners appeared to actively clean the substrate. Small loose rocks (5 - 10 cm in diameter) were rolled around vigorously and fish often wedged themselves between larger rocks (20 - 30 cm in diameter), flexed their bodies, and produced a low rumbling sound as rocks were ground against each other. Spawning fish were often in shallow water (<20 cm) and broke the water's surface with their backs out of the water. The ratio of males to females caught in gillnets was 5:1 on October 13th and 2:1 on October 15th and 16th (Table 4.2).

The earliest confirmed date for oviposition was October 11 when 52 lake trout eggs were found in the stomach of a stocked lake trout sacrificed at Site A (Fig. 4.2). Since an inspection of substrates in the vicinity of Site A failed to produce any evidence of oviposition on this date, other unidentified sites may exist. On four separate occasions, stocked lake trout (2 to 3 at a time) were observed at the spawning site.

On October 14th, 20 eggs were seen on the inshore area of the spawning site and 45 eggs on the offshore area. Oviposition continued on October 15th. No evidence of continued oviposition was found after the nights of October 16th or 17th.

Water temperatures at the spawning site declined slightly from 11.7 ^{o}C on October 13th to 11.1 ^{o}C, on October 18th (Appendix 4(a)). Unusually warm weather prevailed during the entire study, mid-day air temperatures consistently ranged from 14 to 19 ^{o}C (Appendix 4(c)), and mid-lake surface temperatures ranged from 11.8 to 12.0 ^{o}C (Appendix 4(b)).

Ultrasonic Tracking

Ultrasonic transmitter tags were attached to five lake trout: two confirmed females, one confirmed male and two fish of unknown sex (Table 4.3). Fish generally resumed active travel within a few hours of their release rather than remaining offshore for an extended period as was the case on Whitepine Lake in 1983 and on Lake Panache in 1984.

Table 4.3 Ultrasonic transmitter specifications, tagging and release dates and maturity data - Michaud Lake, October, 1984.

Tag #	Output Frequency (Khz)	Pulse Rate (Bpm)	Sex of fish	State of Maturity	Date of Capture	Date of Release
129	66	46	(1)	--	Oct. 10	Oct. 11
130	63	90	Male	Freely flowing	Oct. 11	Oct. 12
111	76	76	Female	Gravid	Oct. 11	Oct. 13
112	75	56	Unknown	--	Oct. 11	Oct. 12
5246	76	60	Female	Gravid	Oct. 12	Oct. 13

(1) - large urogenital pore - possibly a female

Movements of the fish with sonic tags #111, #112, #129, and #130, are marked on Figures 4.3, 4.4, 4.5, and 4.6, respectively. Tags #111 (female) and #112 (sex unknown) were deployed for 8h and 34 h, respectively, before they were torn loose from the fish by gillnets set at the spawning site on October 13th. Female #111 traveled directly to the spawning site from her point of release (Fig. 4.3). Over a period of a day and a half, the movements of tag #112 were concentrated along two shorelines: near the spawning site and opposite sites A and B (Fig. 4.4).

Fish #129 (sex unknown) and male #130 were tracked for 5 and 8 days, respectively. Both fish ranged widely over the lake, although the movements of #129 (Fig. 4.5) were more concentrated along shorelines than were those of #130 (Fig. 4.6). Neither fish was ever located at the spawning site.

Figure 4.3 Movements of sonic tagged female lake trout #111 - Michaud Lake, October 13, 1984.

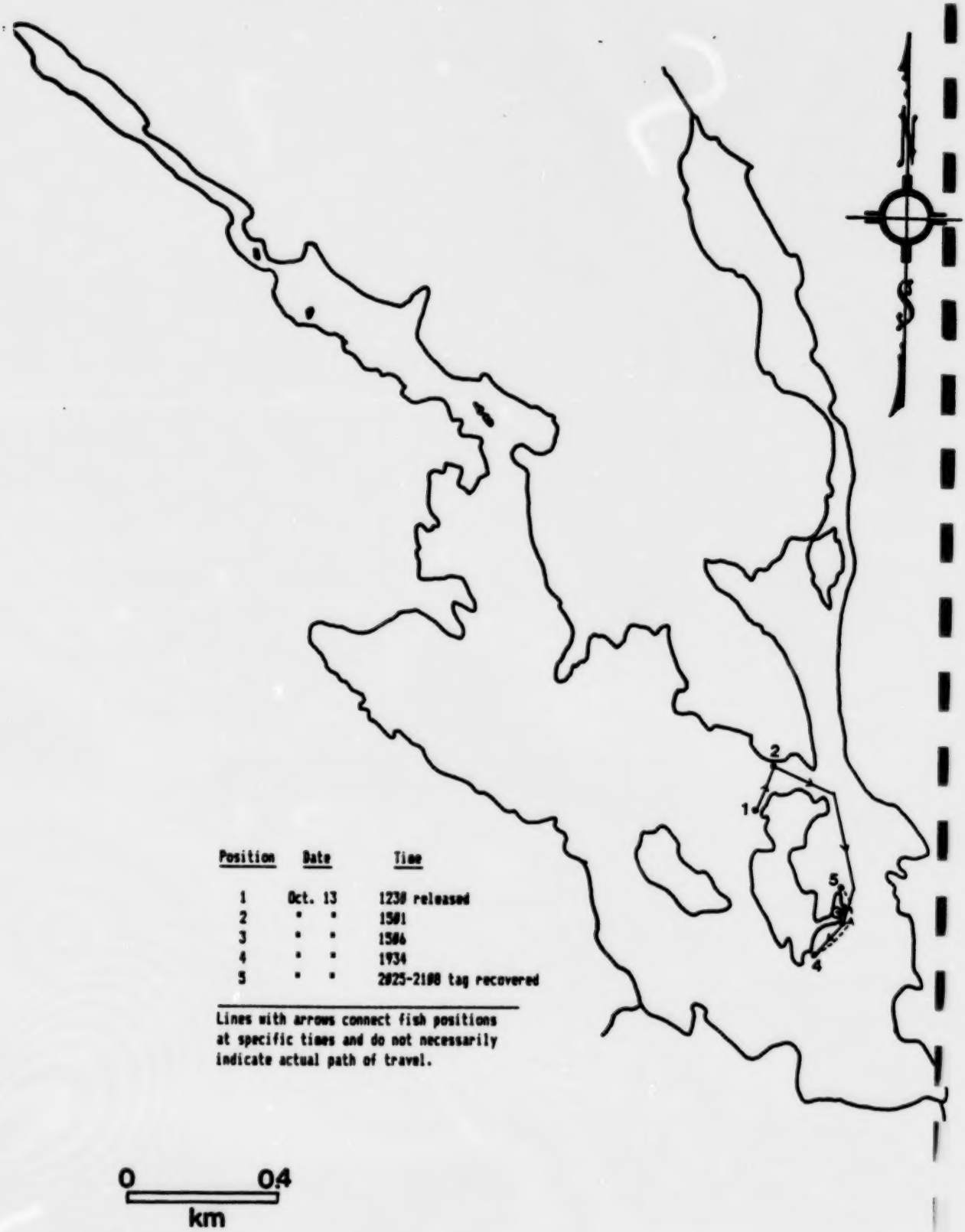
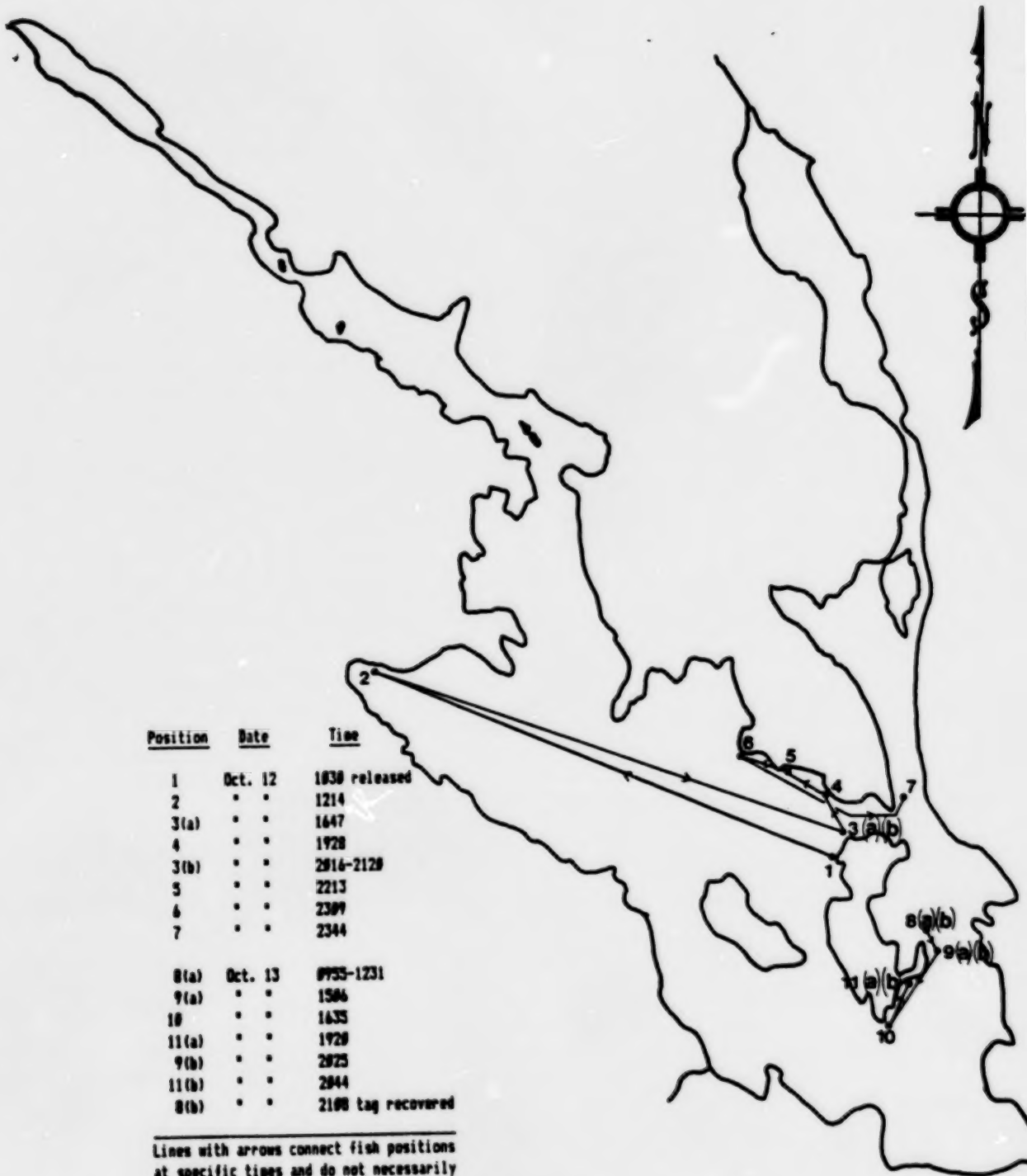


Figure 4.4 Movements of sonic tagged lake trout #112 (sex unknown) in Michaud Lake, October 12 - 13, 1984.

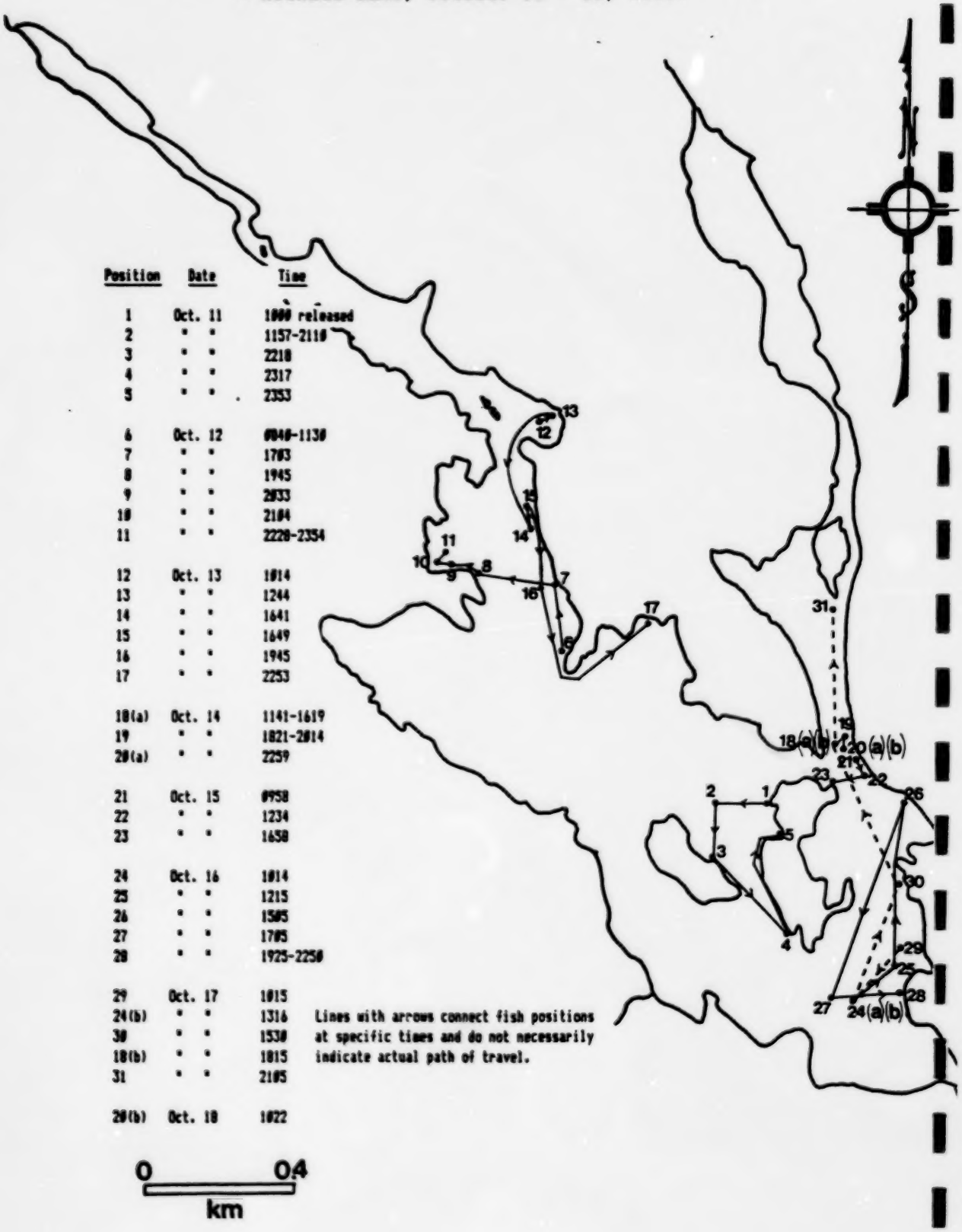


Position	Date	Time
1	Oct. 12	1838 released
2	" "	1214
3(a)	" "	1647
4	" "	1928
3(b)	" "	2016-2128
5	" "	2213
6	" "	2309
7	" "	2344
8(a)	Oct. 13	0955-1231
9(a)	" "	1506
10	" "	1635
11(a)	" "	1920
9(b)	" "	2025
11(b)	" "	2044
8(b)	" "	2108 tag recovered

Lines with arrows connect fish positions at specific times and do not necessarily indicate actual path of travel.

0 0.4
km

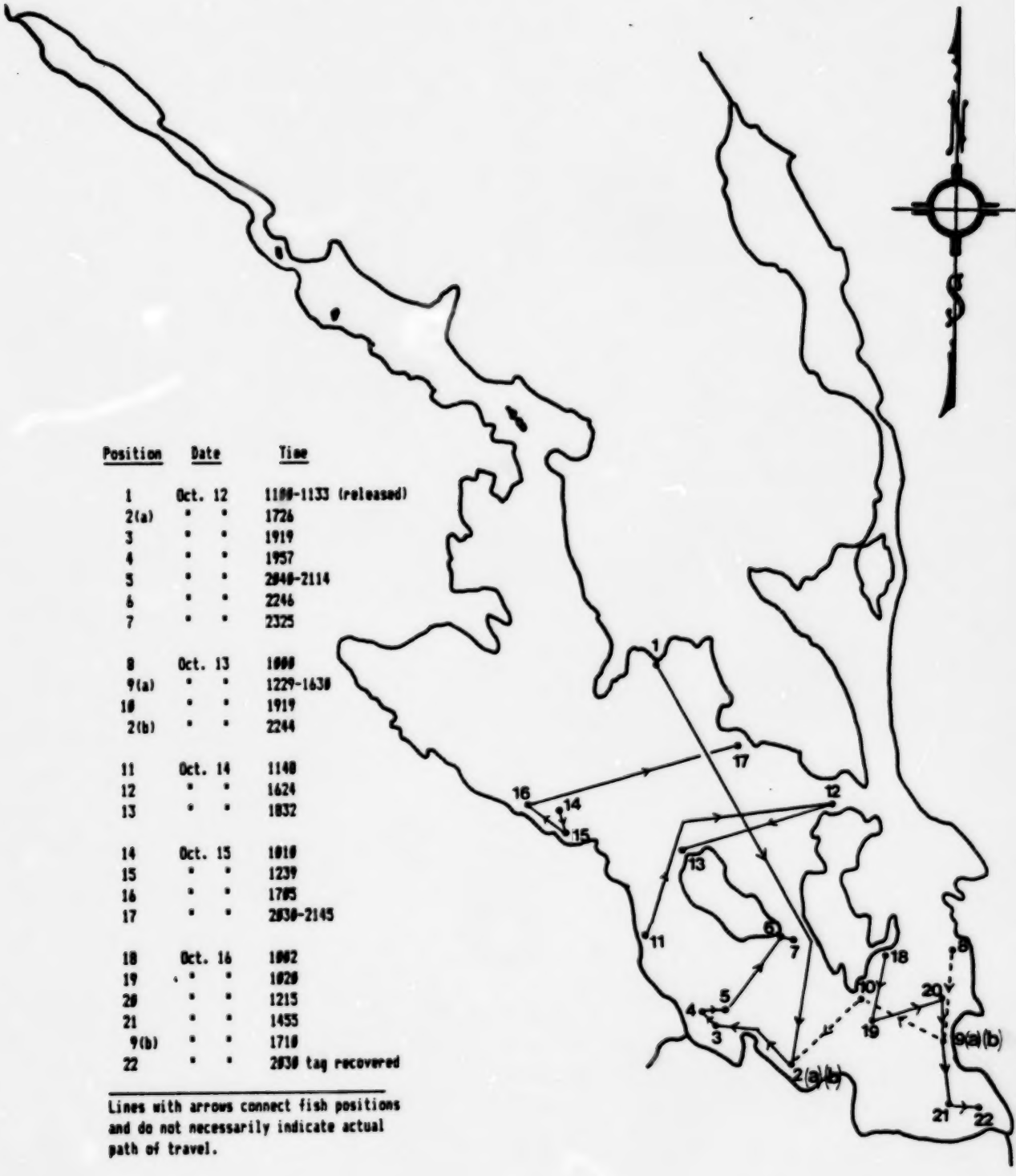
Figure 4.5 Movements of sonic tagged lake trout #129 (sex unknown) - Michaud Lake, October 11 - 18, 1984.



Position	Date	Time
1	Oct. 11	1000 released
2	" "	1157-2110
3	" "	2210
4	" "	2317
5	" "	2353
6	Oct. 12	0040-1130
7	" "	1703
8	" "	1945
9	" "	2033
10	" "	2104
11	" "	2220-2354
12	Oct. 13	1014
13	" "	1244
14	" "	1641
15	" "	1649
16	" "	1945
17	" "	2253
18(a)	Oct. 14	1141-1619
19	" "	1821-2014
20(a)	" "	2259
21	Oct. 15	0958
22	" "	1234
23	" "	1658
24	Oct. 16	1014
25	" "	1215
26	" "	1505
27	" "	1705
28	" "	1925-2250
29	Oct. 17	1015
24(b)	" "	1316
30	" "	1530
18(b)	" "	1815
31	" "	2105
20(b)	Oct. 18	1022

Lines with arrows connect fish positions at specific times and do not necessarily indicate actual path of travel.

Figure 4.6 Movements of sonic tagged male lake trout #130 - Michaud Lake, October 12 - 16, 1984.



Position	Date	Time
1	Oct. 12	1100-1133 (released)
2(a)	" "	1726
3	" "	1919
4	" "	1957
5	" "	2040-2114
6	" "	2246
7	" "	2325
8	Oct. 13	1000
9(a)	" "	1229-1630
10	" "	1919
2(b)	" "	2244
11	Oct. 14	1140
12	" "	1624
13	" "	1832
14	Oct. 15	1010
15	" "	1239
16	" "	1705
17	" "	2030-2145
18	Oct. 16	1002
19	" "	1020
20	" "	1215
21	" "	1455
9(b)	" "	1710
22	" "	2030 tag recovered

Lines with arrows connect fish positions and do not necessarily indicate actual path of travel.

Spawning Site

The spawning site was at the northern tip (Fig. 4.1) of a small (< 0.3 ha) drumlin-shaped island composed of granitic rock and gravel with a forest cover of mature red pine and low shrubs. A ridge ran the length of the island along a north-south axis, rising sharply (slope > 30^{o}) on all sides except at the southern end where the slope is more gradual. Because the site was sheltered from prevailing westerly winds, the wave action necessary to keep substrates clean was limited and, except for a clean narrow band (< 20 cm wide) immediately next to shore, the substrate was evenly coated with a thin layer of periphyton.

Egg deposition was confirmed in two distinct areas (Fig. 4.7): in a small shallow inshore area (area = 0.6 m^2, depth = 6 to 10 cm) with smaller rubble (2 to 10 cm in diameter) and in a larger deeper offshore area (area = 4.2 m^2, depth = 24 to 48 cm) with larger rubble (4 to 25 cm in diameter). Large rocks, 15 to 60 cm in diameter, separated the two areas.

pH and alkalinity values were comparable for the mid-lake basin (pH = 5.66, T.I.P. alkalinity = 0.09 mg/l as $CaCO_3$) and the spawning site (pH = 5.61, T.I.P. alkalinity = 0.07 mg/l) (Table 4.4). Conductivity was higher for spawning site water, 39.1 uS/cm versus 29.9 uS/cm at the mid-lake site, consistent with the probable influx of highly coloured (brown) water from a marshy area north of the spawning site.

Figure 4.7 Overhead view of lake trout spawning site - Michaud Lake, October 1984.

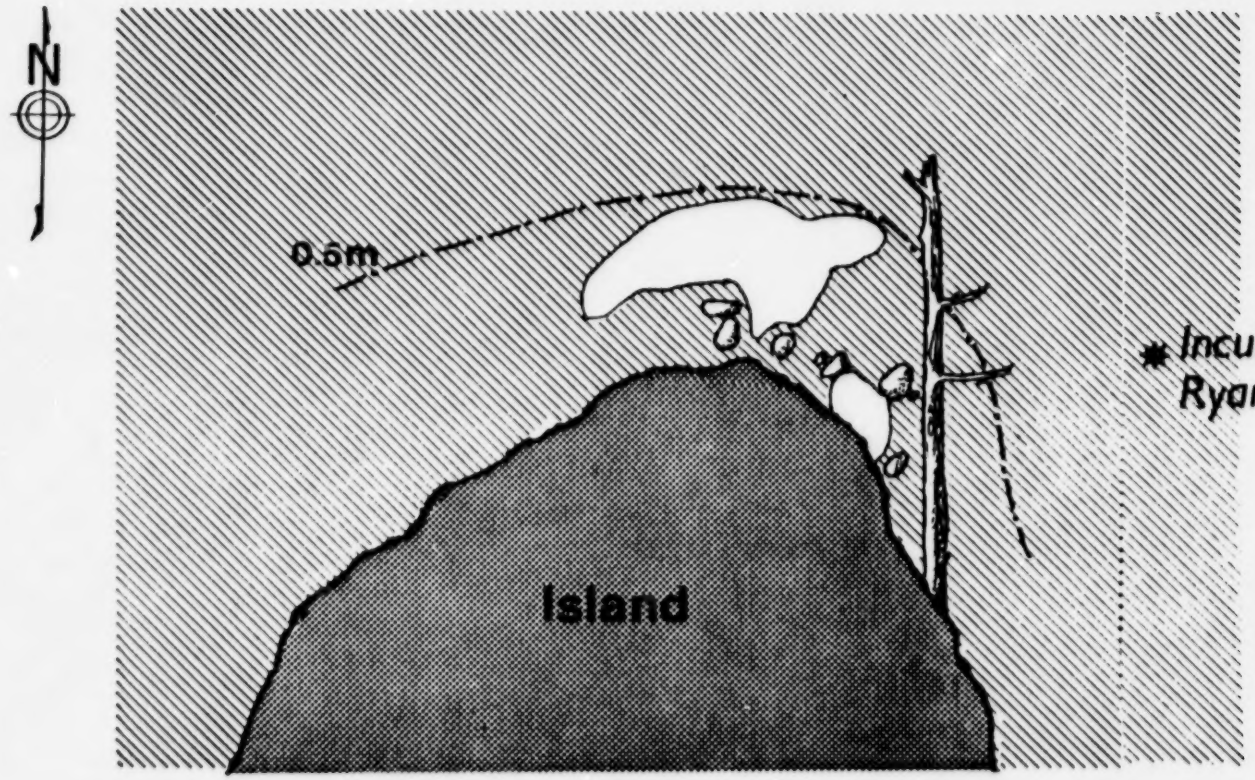


Table 4.4 Spawning site and mid-lake water chemistry data - Michaud Lake, October 15, 1984.

	pH	Alkalinity (mg/l as $CaCO_3$)	Conductivity (uS/cm)	Colour
Spawning Site	5.618	1.5	39.1	slight yellow
Mid-lake	5.664	1.9	29.9	clear

Mid-lake sampled with 15 m tube composite sampler.

Gamete Viability

Two females and three males provided eggs and milt for the test of gamete viability. A single batch of eggs stripped from female B55805 (Table 4.1) and fertilized by male B55810 was loaded into incubator tray #1. Two batches of eggs, stripped from female B55813, were fertilized separately by two different males, B55811 and B55812, and were then combined in incubator tray #2.

When incubator trays were retrieved on January 22, 1985, live eggs and free embryos were found only in the periphery of each tray. Dead eggs and masses of fungal growth were found in the central portion of each tray where complete egg mortality was likely related to the high density of eggs initially installed. Once fungal infection had attained a foothold, the eggs provided a good medium for fungal growth. Percent survival (live eggs and free embryos combined) was 8.5 for tray #1 and 40.1 for tray #2 (Table 4.5). Most eggs appeared to have died in the pre-eyed stage: 62.3% in tray #1 and 43.5% in tray #2.

At installation, water temperature at the incubation site was 11.1 ^{o}C, then dropped gradually to 7.8 ^{o}C by October 30, 1984, and by November 21, 1984, had leveled off at 1.0 ^{o}C. In January 1985, water temperature was 0.2 ^{o}C and dissolved oxygen was 12 ppm.

TABLE 4.5 Number and percent[1] of mortalities and survivors in an incubation experiment with fertilized lake trout eggs from native spawners on Michaud Lake - October 14, 1984 to January 22, 1985.

	Tray #1 (552 eggs installed)[2]		Tray #2 (829 eggs installed)	
	#	%	#	%
MORTALITIES				
Pre-eyed egg	344	62.3	361	43.5
Eyed egg	161	29.2	136	16.4
Total	505	91.5	497	59.9
SURVIVORS				
Eyed egg	41	7.4	264	31.9
Free embryos	6	1.1	68	8.2
Total	47	8.5	332	40.1

(1) Percent of total number of eggs installed.
(2) Count of number of eggs installed was made after trays were retrieved.

5. MARINA LAKE (pH 5.15) - 1985

In 1958, the first survey of Marina Lake (OMNR Temagami District file report) reported the following species: lake trout, brook trout, common white sucker and walleye (*Stizostedion vitreum vitreum*). There are unverified reports of aurora trout (*Salvelinus fontinalis timagamiensis*) being caught in Marina Lake (Sale 1967). There is no history of stocking with hatchery-reared fish. Netting surveys from 1962 and 1969 list the same species as the 1958 survey with the exception of walleye.

A recent netting survey (OMNR 1983b) reported a catch of 2 lake trout, 5 brook trout, 48 common suckers and 1,891 yellow perch, a species not previously reported. The recent abundance of yellow perch may reflect the greater tolerance of this species to acidic conditions (Beamish et al. 1975) as well as reduced predation and competition for food from less acid-tolerant species. Brook trout were reproducing successfully according to this survey, but the lake trout appeared to be experiencing recruitment failure.

This section describes a lake trout spawning assessment conducted on the lowest pH lake, Marina Lake (pH 5.15), in October 1985.

METHODS

Shoreline inspections commenced October 16th and were conducted between dusk and 2300 h in search of spawning lake trout or evidence of substrate cleaning. Nets were set in various locations around the lake on October 16th and 17th. Thereafter, netting was restricted to the mid-lake shoal (Fig. 5.1).

Figure 5.1 Map of Marina Lake showing depth contours (m) and location of lake trout spawning site.

Ultrasonic transmitter tags were attached to two adult lake trout. Tracking commenced October 24th and continued until October 30th. The fish were located several times throughout the day and approximately every hour after dark until midnight. When sonic tagged fish were followed to the shorelines, these areas were checked for the presence of other lake trout and for evidence of substrate cleaning and deposition of eggs. On alternating days, during the period October 16 - 30, 1985, dissolved oxygen and water temperature profiles (Appendix 5) were recorded at 1 m intervals in the main basin of the lake with a YSI Model 54A dissolved oxygen-temperature meter.

RESULTS

Status of Spawning Population

Of four adult lake trout observed at the offshore spawning site (Fig. 5.1), three fish - two females and one male - were caught and released (Table 5.1). One of each sex also received an ultrasonic transmitter tag. Although the fourth fish was not captured, it was likely a male based on its dark lateral stripe and its aggressive behaviour toward the known male.

Table 5.1 Morphological features and other data for spawners - Marina Lake, October, 1985.

Tag #	Date Caught	Length(cm) Total	Fork	Weight (g)	Sex	Remarks
36140	Oct. 18	64.9	59.0	2500	Ripe male	sonic tag 23
36142	Oct. 22	55.1	50.9	1750	Firm female	
36143	Oct. 22	60.9	55.9	2250	Firm female	sonic tag 14

Spawning Observations

Ideal viewing conditions on October 28th (Table 5.2) facilitated observations of spawning activity. Between 1910 and 2200 h, four fish - two sonic tagged fish, one streamer tagged female and the unconfirmed male - were observed at the spawning site. The fish swam about in pairs or as a group of three or four. Males swam alongside or slightly below and behind a female, sometimes nudging her. Vigorous sweeping motions of the tail were made over rocks to the extent that low rumbling sounds were generated as rocks were moved around. The light from the headlamp appeared to disrupt spawning behaviour, as after a short time they would swim off. On October 28th, water temperature (10.2°C) and dissolved oxygen (10.1 mg/l) were uniform throughout the water column (Appendix 5).

Table 5.2 Daily weather conditions and observations of fish on the mid-lake spawning site. Marina Lake, October 16 - 29, 1985.

Date	Weather	Viewing Conditions	Observations
Oct. 16	Slight W wind, 100% cloud	Good	No trout sighted or caught in nets
" 17	Strong SE wind, 100% cloud	Poor	" " " " " " "
" 18	Light N wind, 10% cloud	Good	Sighted and captured one male trout
" 19	Slight N wind, 0% cloud	Poor	No trout sighted or caught in nets
" 20	Calm, 0% cloud	Excellent	" " " " " " "
" 21	Calm, 0% cloud	Excellent	" " " " " " "
" 22	Not recorded	-----	Captured two female trout, one sucker
" 23	Strong SW wind, 100% cloud	Poor	No trout sighted or caught in nets
" 24	Strong SW wind, 100% cloud Hailstorm at 1930, clearing later	Poor to Good	" " " " " " "
" 25	W wind, 0% cloud	Poor	No trout sighted (stopped setting nets)
" 26	S wind, 100% cloud	Poor	" " "
" 27	Very strong N wind, 100% cloud	Poor	" " "
" 28	Calm, 0% cloud	Excellent	Sighted 4 trout exhibiting spawning behaviour
" 29	S wind, 90% cloud	Poor	Sighted one sonic tag

Although oviposition was not directly observed on the evening of October 28th, 20 eggs were counted at the site the next morning. An increase in egg count (> 80) on October 30th confirmed that oviposition was continuing; however, the end of spawning was not determined since the field program was terminated on October 30th.

Ultrasonic Tracking

One fish of each sex received an ultrasonic transmitter tag. Tag specifications and other data are listed in Table 5.3. A ripe male (tag #23) was captured on October 18th at the spawning site and was held until October 21st before release. A female (#14) was captured at the spawning site on October 22nd and was released at the site on October 23rd. Neither the sonic tagged female nor a second female caught at the same time (Table 5.1) released eggs freely during handling.

Table 5.3 Ultrasonic tag specifications, Marina Lake - October, 1985.

Tag #	Pulse Rate (beats/minute)	Output Freq. (khz)	Date Fitted	Date Released	Sex of fish
14	80	60	Oct. 23	Oct. 23	Female
23	74	79	Oct. 19	Oct. 21	Male

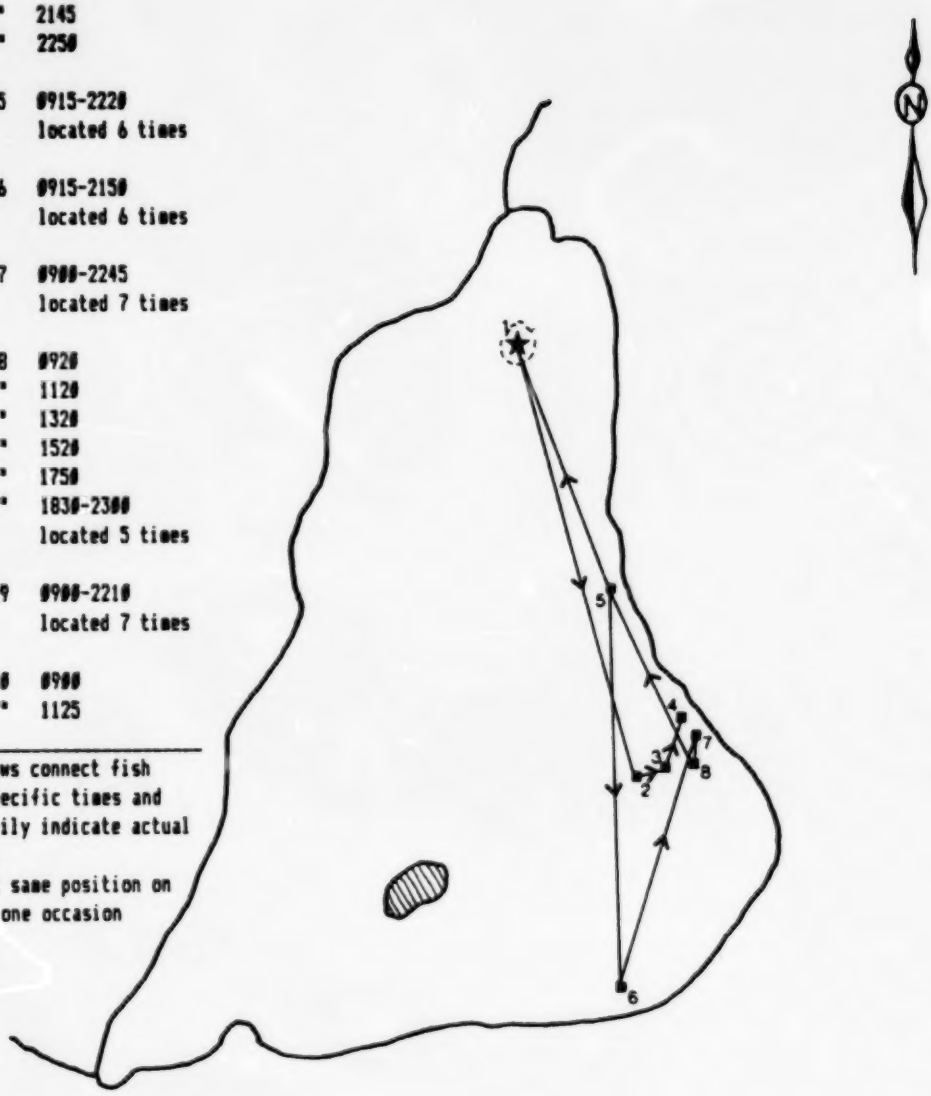
Tracking commenced on October 24th; thus, the female had been tagged for 1 day and the male for 5 days prior to the start of tracking. The male stayed near the spawning site with two exceptions (Fig. 5.2): on October 24th, he was located on the shoal at twilight but soon moved to the southeast portion of the

Figure 5.2 Movements of sonic tagged male lake trout #23 in Marina Lake, October 24 - 30, 1985.

Position	Date	Time
1	Oct. 24	1830
2	"	2015
3	"	2145
4	"	2250
1*	Oct. 25	0915-2220 located 6 times
1*	Oct. 26	0915-2150 located 6 times
1*	Oct. 27	0900-2245 located 7 times
5	Oct. 28	0920
6	"	1120
7	"	1320
8	"	1520
5*	"	1750
1*	"	1830-2300 located 5 times
1*	Oct. 29	0900-2210 located 7 times
1*	Oct. 30	0900
1*	"	1125

Lines with arrows connect fish positions at specific times and do not necessarily indicate actual path of travel.

* - located at same position on more than one occasion



Spawning Site

0 0.5

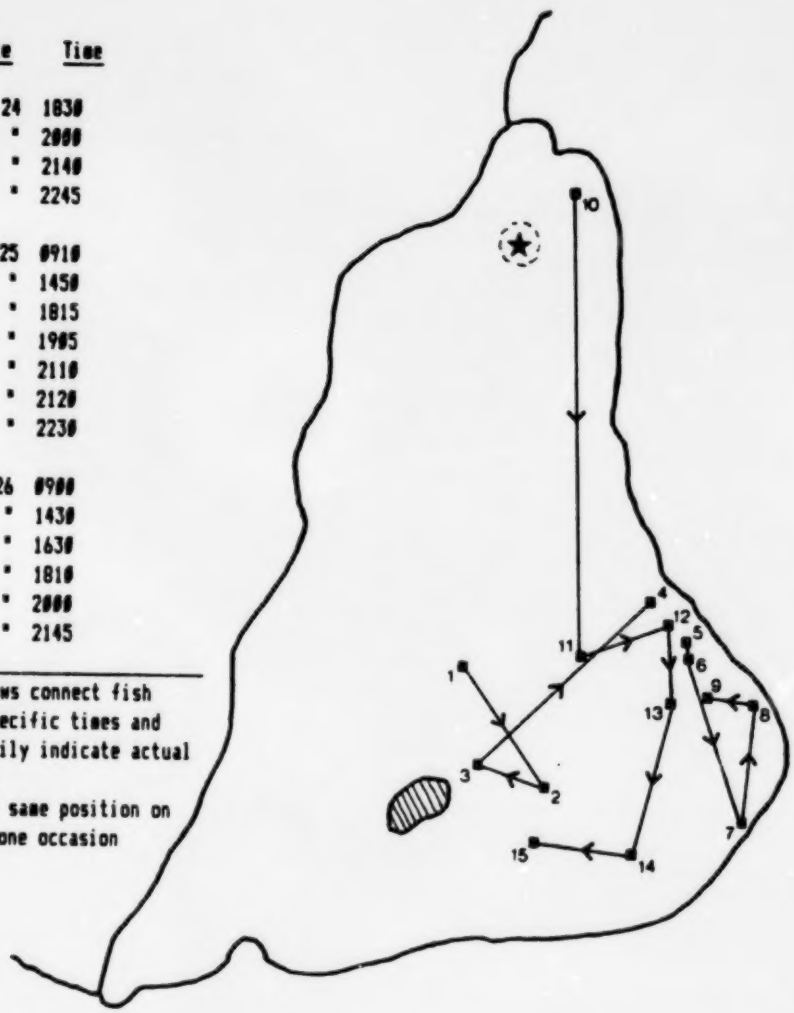
km

Figure 5.3(a) Movements of sonic tagged female lake trout #14 in Marina Lake, October 24 - 26, 1985.

Position	Date	Time
1	Oct. 24	1830
2	"	2000
3	"	2140
4	"	2245
5	Oct. 25	0910
6	"	1450
6*	"	1815
6*	"	1905
7	"	2110
8	"	2120
9	"	2230
10	Oct. 26	0900
11	"	1430
12	"	1630
13	"	1810
14	"	2000
15	"	2145

Lines with arrows connect fish positions at specific times and do not necessarily indicate actual path of travel.

* - located at same position on more than one occasion



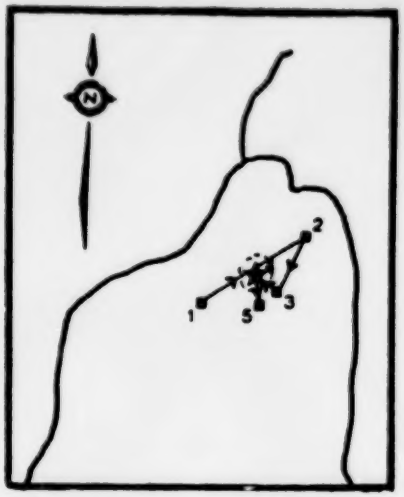
Spawning Site

0 0.5

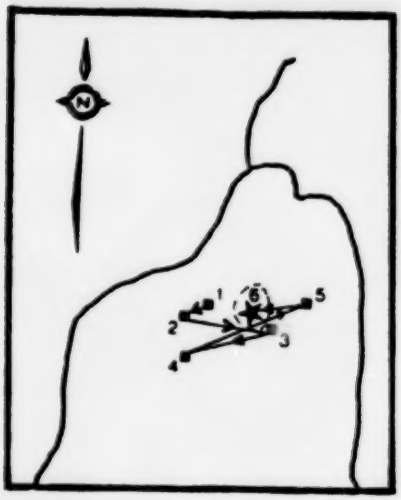
km

Figure 5.3(b) Movements of sonic tagged female lake trout #14 in Marina Lake, October 27 - 30, 1985.

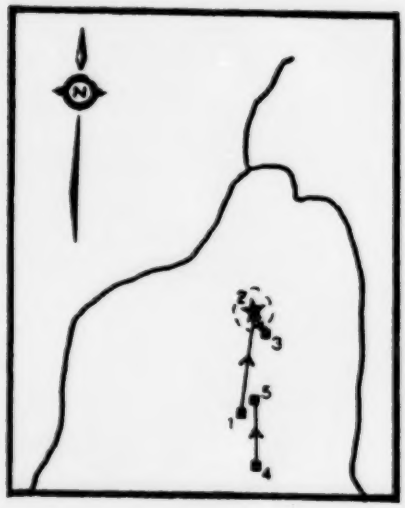
Position	Date	Time
1	Oct. 27	0905
2	"	1525
3	"	1740
4	"	1900
5	"	2020
5*	"	2140
5*	"	2245



Position	Date	Time
1	Oct. 28	0915
2	"	1125
3	"	1325
4	"	1525
5	"	1720
6	"	1830-2300 located 5 times



Position	Date	Time
1	Oct. 29	0900
2	"	1550-1940 located 4 times
3	"	2140
3*	"	2240
4	Oct. 30	0905
5	"	1125



Lines with arrows connect fish positions at specific times and do not necessarily indicate actual path of travel.

* - located at same position on more than one occasion

Spawning Site

0 0.5 km

lake and stayed there for the remainder of the evening; and on October 28th, the date oviposition was first confirmed, he was found in the southeast section of the lake during daylight and then near dusk moved back onto the spawning site.

The female was usually found in the southeast end of the lake during the first three days of tracking (Fig. 5.3(a)) and on the morning of October 27th moved to the spawning site (Fig. 5.3(b)). In general, she ranged more widely than the male who, during the course of field observations, covered a minimum total distance of 2755 m which is 67% of the female's minimum of 4135 m.

Spawning Site

Only one spawning site was found and no lake trout were sighted at any other potential sites. The spawning site was situated on a mid-lake shoal at the north end of the lake with the nearest shore lying approximately 75 m to the northwest (Figure 5.1). The site lies in 3 m of water and the substrate consists of smooth-rounded rock, 5 to 15 cm diameter, and large boulders, 20 to 50 cm in diameter, sparsely scattered over a base of coarse and fine gravels. Eggs were deposited over an area of roughly 2 m^2 on the south side of a large boulder lying on a gradual slope.

The site on Marina Lake is not exposed to the prevailing northwesterly winds as are the sites on Whitepine Lake, Laundrie Lake and Lake Panache. Instead, the site may be exposed to summertime prevailing southwesterly winds that keep the site clear of silt and detritus.

6. LAKE PANACHE (Reference Lake - pH 6.4) - 1984

Lake Panache served as a circumneutral (pH 6.4) reference lake (Fig. 1.0) for spawning assessment studies. This lake currently provides good angling for lake trout. Lake Panache has received numerous plantings of hatchery-reared lake trout but recent creel surveys indicate that the majority of angled lake trout are natural recruits (unpublished creel data, OMNR Sudbury District).

This section presents the results from a lake trout spawning assessment conducted on Lake Panache in October 1984.

METHODS

Preliminary mapping of shorelines was conducted during daylight hours October 2 - 3, 1984, to identify potential spawning sites in the central and eastern parts of the lake. Substrates were classified as suitable for spawning if clean rock rubble 5 to 20 cm in diameter was present in depths of water less than 2.0 m. Weather and time restrictions did not permit mapping of this large lake (7,735 ha).

During the period October 15 - 29, 1984, field observations were conducted every evening from twilight to 2300 hours in those areas identified as potential spawning sites. Sightings of fish and evidence of any substrate cleaning activity were noted.

Morphological and maturity data were obtained from lake trout captured along shorelines. Fish were anesthetized, measured and tagged with yellow disc tags.

Ultrasonic transmitter tags were attached to selected adults for tracking them to spawning beds. Tracking was restricted to two major basins, the central and eastern basins, except on

October 20th and 24th when shorelines were checked at the west end in the vicinity of Walker Lake Dam and Chief Island (Fig. 6.1).

Once spawning sites were located the extent of egg deposition was determined by a SCUBA diver. Mid-lake water temperature and dissolved oxygen profiles were periodically recorded in the north central basin (Appendix 6). Temperature and dissolved oxygen were also recorded at the spawning beds on several occasions.

RESULTS

Status of Spawning Population

Thirty one (31) spawners were captured at 4 sites and of these, 21 were males (Table 6.1 and Fig. 6.1). Fork lengths (sexes combined) ranged from 49.4 cm to 78.3 cm and weights from 1000 g to 5000 g. Mean fork length for females (61.3 $\pm$ 6.9 cm) was greater than that for males (59.0 $\pm$ 8.3 cm). On October 22nd, the ratio of males to females for the combined catch from Morin Island and MacLean's Island was 2:1.

Spawning Observations

Starting October 15, 1984, observations at Ranger Island and Maclean's Island (Fig. 6.1) indicated that a few lake trout were moving onto spawning beds. Four ripe males were netted, tagged and released (Table 6.1). Water temperature was 12.6^{o}C. On October 18th, two females (eggs not flowing freely) were captured at Maclean's Island, along with two ripe males. The first reported sighting of lake trout had been at Morin Island on October 10th - five days prior to the start of our field observations (H. Vouk, cottage owner, personal communication).

Table 6.1 Summary of lake trout captured during spawning assessment on Lake Panache - October, 1984.

#	Date Caught	Location	Length (cm) Total	Length (cm) Fork	Weight (g)	Sex	Tag Number	Comments
1	October 15	Ranger Island	66.1	60.5	2150	Ripe male	B55826	
2	" "	MacLean Island	64.3	58.6	1830	Ripe male	B55827	
3	" 17	MacLean Island	54.7	49.4	1260	Ripe male	B55828	
4	" "	MacLean Island	62.3	56.3	1890	Ripe male	B55829	
5	" 18	MacLean Island	72.0	66.3	4500	Female	B55816	Sonic tag 130
6	" "	MacLean Island	58.9	53.2	1680	Female	B55817	Sonic tag 111
7	" "	MacLean Island	57.4	52.6	1615	Ripe male	B55818	Sonic tag 112
8	" "	MacLean Island	58.9	53.5	1590	Ripe male	B55819	
9	" 19	Morin Island	57.5	52.2	1100	Ripe male	B55820	* See Note 1.
10	" "	Morin Island	74.5	67.5	3600	Ripe male	B55821	
11	" "	Morin Island	84.2	77.4	5000	Ripe male	B55822	
12	" "	Morin Island	77.0	71.5	4200	Ripe male	B55823	
13	" "	Morin Island	78.3	74.2	3850	Ripe male	B55824	
14	" "	Morin Island	56.5	51.2	1200	Ripe male		Not tagged
15	" "	Morin Island	69.8	62.5	2850	Ripe male		Not tagged
16	" 20	Walker Bay South	63.6	57.2	1985	Ripe male	B55830	
17	" "	Walker Bay South	78.2	71.8	5000	Ripe female	B55831	
18	" "	Walker Bay South	68.5	62.1	3000	Ripe male	B55832	
19	" "	Walker Bay South	64.1	57.8	--	Ripe female	B55833	
20	" "	Walker Bay South	63.2	57.0	2250	Ripe male	B55834	
21	" 22		65.6	59.5	2300	Ripe female	B55836	
22	" "	(#21-32 were	77.5	71.2	5000	Female	B55837	
23	" "	captured at	56.7	51.0	1000	Ripe female	B55838	
24	" "	Morin Island and	69.0	63.2	2400	Ripe female	B55839	
25	" "	MacLean Island.	65.3	59.6	2250	Ripe female	B55840	
26	" "	Transferred to	58.3	52.5	1000	Ripe male	B55841	
27	" "	Michaud lake on	75.4	68.8	3750	Ripe male	B55842	
28	" "	October 23)	65.1	59.6	2100	Ripe male	B55843	
29	" "		58.0	52.3	1100	Ripe male	B55844	
30	" "		54.7	49.5	1000	Ripe male	B55847	
31	" "		65.0	59.3	2500	Ripe female	B55835	

Note 1. - Recaptured on October 22nd and retagged with B55846 for transfer to Michaud

Figure 6.1 Lake trout spawning sites, fish sightings, and sites with potential for lake trout spawning. Lake Panache, October 1984.

Vouk also mentioned that at Morin Island spawning generally started later in October; a year earlier, in 1983, he first observed lake trout at the site around October 22nd.

On October 19th, the first major concentration of lake trout was observed at Morin Island. A rough count of nine fish was made during the initial pass and seven ripe males were subsequently captured and tagged. On successive nights the fish count at Morin Island increased and reached a high of 90 on October 20th (Table 6.2). That same evening, 62 individuals were observed at Maclean's Island.

Smaller groups of lake trout were observed at three sites at the west end of the lake and at two sites at Ranger Island (Fig. 6.1). On October 20th, eight adults were sighted in a small bay to the east of Walker Lake Dam. Three ripe males and two ripe females were captured, tagged and released. Although the site is well exposed to wind, the rock substrate was not clean. The same night, three trout were also observed off the southwest of Ranger Island and one fish was spotted off the northwest side. Suitable substrate was available at both sites but there was no evidence of cleaning or oviposition. On October 24th, one lake trout was seen on clean rubble off the northwest shore of Chief Island and another three were spotted near Ling Point where subsequent inspection by a SCUBA diver failed to reveal any eggs.

Spawning peaked around October 20th based on the numbers of fish seen on active beds. Surface water temperature was 12.3^{o}C (Table 6.3). Fewer fish were seen at Maclean's Island (n=62) than at Morin Island (n=90) where better viewing conditions were usually encountered.

Table 6.2 Number of lake trout observed on Morin Island and Maclean's Island spawning sites and prevailing weather conditions - Lake Panache, October 1984.

DATE	FISH COUNT (1) Morin Island	MacLean's Island	WEATHER CONDITIONS
15	NC	4	Clear, calm, moonlight
16	NC	0	Clear, calm, moonlight
17	NC	5	Overcast, W wind after 2000
18	NC	NE *	Slight W wind
19	9	0 *	Moderate W wind after 2030
20	90	62	15% cloud, calm after 1900
21	70+	9 *	Overcast, moderate NNW wind
22	NE *	NE *	50% overcast, strong W wind
23	NC	NC	---
24	40	5 *	Slight overcast, moderate W wind
25	9	0 *	Overcast, rain, moderate E wind
26	2 *	0 *	Overcast, rain, strong east wind
27	6 *	0 *	Foggy, moderate S wind
28	1	6	Slight SW winds
29	2	0	---

(1) - Highest count recorded during one pass, not cumulative total for evening
NC = Not checked
NE = Fish seen but no estimate of numbers
* = Poor viewing conditions

Table 6.3 Summary of water temperature (Temp.) and dissolved oxygen (D.O.) on spawning beds - Lake Panache 1984.

Date	Morin Island Temp. (°C)	Morin Island D.O. (mg/l)	Maclean's Island Temp. (°C)	Maclean's Island D.O. (mg/l)
October 19	13.0	9.7	-	-
" 21	*	*	12.3	9.2
" 25	11.4	-	11.8	8.7
" 26	11.2	-	-	-
" 29	11.3	9.2	-	-

* - Meter malfunctioned

Spawning was finished by October 29th; only two fish swam briefly over the shoal at Morin Island during the entire evening. Surface water temperature was 11.3°C.

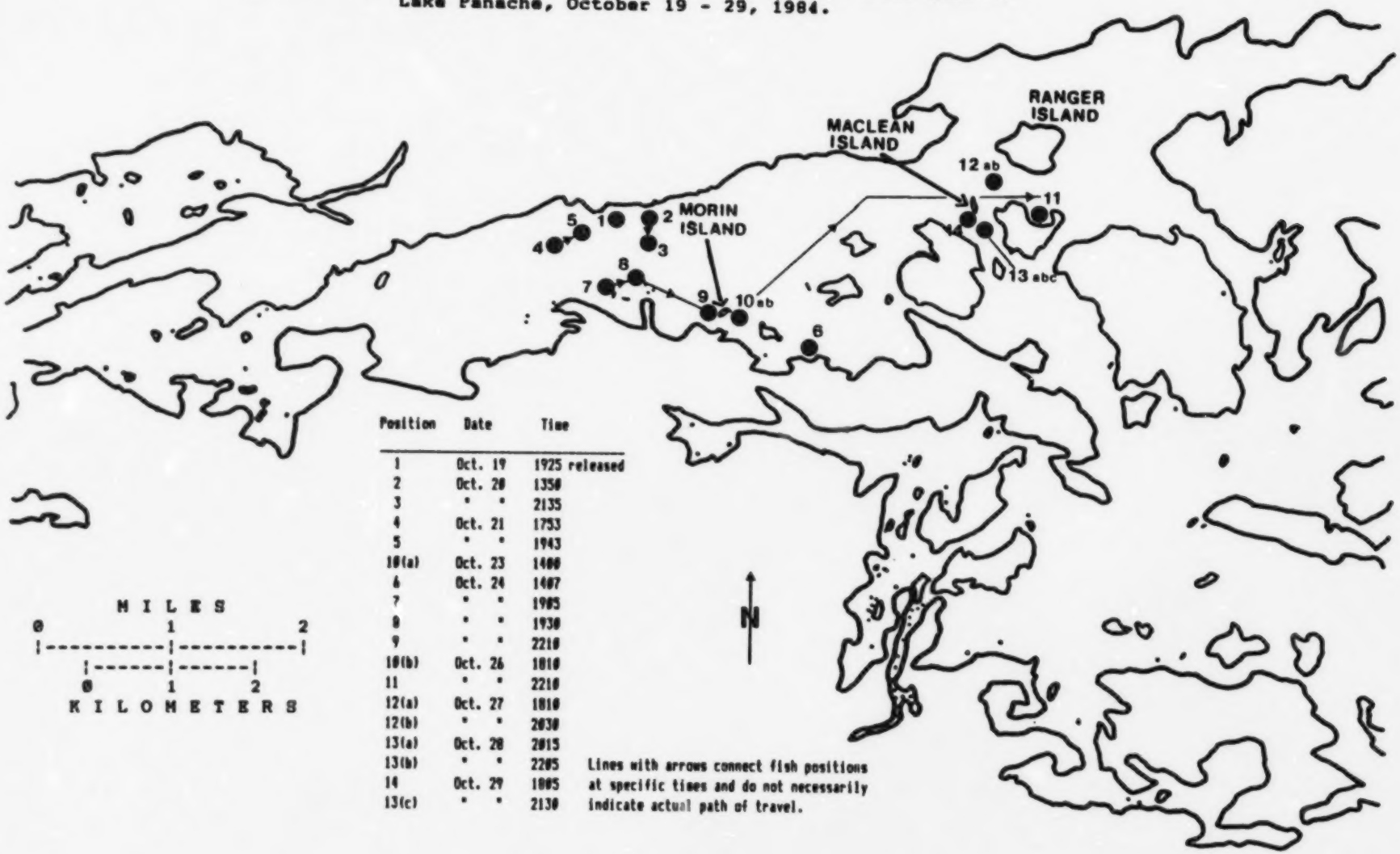
At times, lake trout were observed in groups of 10 to 20 individuals, swimming on their backs in tight circular clusters close to the bottom. Their white abdominal colouration was quite noticeable and there was no doubt that their attitude was inverted. This observation was made at Morin Island on October 20th, 21st and 24th and at Maclean's Island on the 28th. There is no mention of such behaviour in the literature.

Ultrasonic Tracking

On October 18th, ultrasonic transmitter tags were attached to three fish, two females and one male, captured at Maclean's Island. Only the male was fully ripe. Morphological data are listed in Table 6.1 and movements of female #130 and male #112 are illustrated in Figs. 6.2 and 6.3, respectively. One tag, #111 attached to a female, ceased transmitting after two days.

Handling and tagging affected fish behaviour longer than had been previously observed on other study lakes. Five days elapsed before a tagged fish was found near a spawning bed - male #112 was located off Morin Island on October 23rd (Fig. 6.3). In contrast, on Laundrie and Whitepine Lakes in 1983, fish remained relatively stationary offshore for only 24 h before resuming regular visits to spawning sites. After October 23rd, the male did not frequent either Morin Island or Maclean's Island. On October 28th, the female was located off the shoal at Maclean's Island but did not appear on the confirmed site of egg deposition.

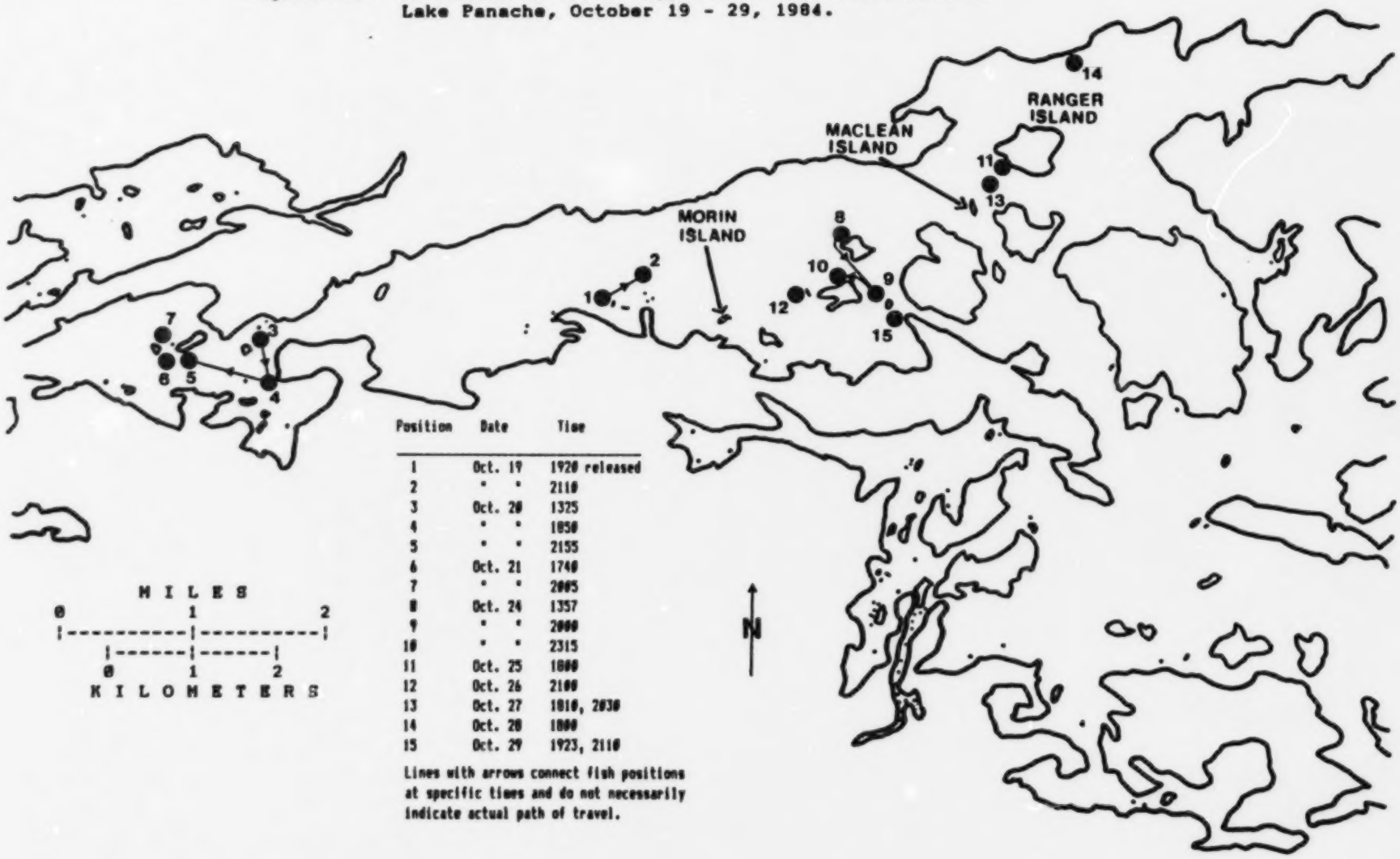
Figure 6.2 Movements of sonic tagged female lake trout #130 in Lake Panache, October 19 - 29, 1984.



Position	Date	Time
1	Oct. 19	1925 released
2	Oct. 20	1350
3	" "	2135
4	Oct. 21	1753
5	" "	1943
10(a)	Oct. 23	1400
6	Oct. 24	1407
7	" "	1905
8	" "	1930
9	" "	2210
10(b)	Oct. 26	1810
11	" "	2210
12(a)	Oct. 27	1810
12(b)	" "	2030
13(a)	Oct. 28	2015
13(b)	" "	2205
14	Oct. 29	1005
13(c)	" "	2130

Lines with arrows connect fish positions at specific times and do not necessarily indicate actual path of travel.

Figure 6.3 Movements of sonic tagged male lake trout #112 in Lake Panache, October 19 - 29, 1984.



Position	Date	Time
1	Oct. 19	1920 released
2	" "	2110
3	Oct. 20	1325
4	" "	1850
5	" "	2155
6	Oct. 21	1740
7	" "	2005
8	Oct. 24	1357
9	" "	2000
10	" "	2315
11	Oct. 25	1800
12	Oct. 26	2100
13	Oct. 27	1810, 2030
14	Oct. 28	1800
15	Oct. 29	1923, 2110

Lines with arrows connect fish positions at specific times and do not necessarily indicate actual path of travel.

Both sonic tagged fish ranged widely (Figs. 6.2 and 6.3). The greatest rate of travel was recorded for the female who in 4 hours covered a distance of 4.2 km on October 26th between 1810 and 2210 h.

Spawning Sites

Oviposition was confirmed at two sites: Morin Island and Maclean's Island (Fig. 6.1). Groups of fish were also observed at three other sites with rock rubble substrate - west of Ling Point, east of Walker Dam and off Ranger Island (Fig. 6.1) - but no eggs were found.

At Morin Island, the spawning site was located off the north side of the island and ran along the base of a steep rock face for a distance of ~25 m. The shoal extended offshore for ~10 m and had a relatively uniform water depth of 1.25 - 1.50 m. The substrate consists of a flat expanse of broken angular rubble, 10 to 20 cm in size. Smaller rock, less than 10 cm in diameter, were found on the western edge of the shoal.

Eggs were distributed over the entire site at Morin Island with a heavy concentration in the middle area where lake trout were most often observed. Numerous eggs were also found on the steep slope on the offshore edge of the site.

At Maclean's Island, the spawning site was located on a shoal which extended in a southerly direction from the southern tip of the island for a distance of ~60 m and consisted of a long spine of large rocks and boulders. On the east side the shoal dropped quickly to deeper water, while on the shallower west side, interspersed among the large rocks, there were small areas of

relatively smooth rubble, 10 cm in diameter. Patchy areas of moss-like submergent aquatic vegetation and algae were scattered over the substrate. Lake trout restricted their spawning activity to a 15 m^2 area in 1.8 m of water, halfway out along the west side of the shoal (30 m from shore) in an area clear of algae and vegetation.

7.0 SUMMARY

Small numbers of old native lake trout continue to spawn in the four low pH lakes. The number of spawners observed on spawning beds ranged from a low of two fish in Laundrie Lake to a high of twenty-two in Michaud Lake.

In two cases there is evidence that viable gametes were produced. Viability was confirmed on Michaud Lake and fertilized eggs were previously found at site SS (Fig. 2.1) on Whitepine Lake (Gunn and Keller 1984).

Adult transfers appear to be a viable option for rehabilitating declining populations. On Whitepine Lake transplants participated in spawning within a year of their introduction to new waters. Similar findings have been reported from the neutralization study on Bowland Lake (Booth et al. 1987).

Only on Marina Lake did spawning occur at an offshore shoal; elsewhere, fish spawned at shoreline sites (Table 7.1). Two sites, one on Michaud Lake and the other on Marina Lake, were sheltered from prevailing northwesterly winds but only on Michaud was the site covered with silt and detritus. Presumably, the site on Marina Lake is kept clean by prevailing summer southerly winds. Substrates encountered at spawning sites ranged from a gravel base with scattered rock on Marina Lake to uniformly-sized sharp angular rock on Lake Panache.

Table 7.1 Summary of physical features of lake trout spawning sites on study lakes.

Lake	No. of sites	Range of Depths (cm)	Substrate Type	Substrate Size (cm)	Exposed to Prevailing Winds?	Risk of Exposure to Run-off	Active Cleaning Confirmed?
Whitepine	4	40 - 150	rock rubble some gravel	5 - 20	Yes	Moderate to high	Yes
Laundrie	1	18 - 70	rock rubble	2 - 5	Yes	High	No
Michaud	1	6 - 40	rock rubble	2 - 25	No	Moderate	Yes
Marina	1	3 m	scattered rock on gravel base	0.5 - 50	No	Low	No
Panache	2	125 - 180	sharp angular rock	10 - 20	Yes	Negligible	No

Table 7.2 Timing of peak spawning activity in relation to date and water temperature at spawning sites.

Lake	Date of peak activity	Temperature (^{o}C)
Whitepine	Oct. 23, 1983	8.4
Laundrie	Oct. 26, 1983	6.4
Michaud	Oct. 15, 1984	11.7
Panache	Oct. 20, 1984	12.3
Marina	Oct. 28, 1985	10.2

During the three study years (1983-1985), spawning occurred from the middle of October to the end of October (Fig. 7.2) at water temperatures ranging from a low of 6.4 ^{o}C on Laundrie in 1983 to a high of 12.3 ^{o}C on Lake Panache in 1984.

In common with observations by MacLean et al. (1981) on Lake Opeongo, female lake trout in Whitepine Lake and Marina Lake traveled more than males. Tagged fish also covered considerable distances as in Lake Panache where one female swam 4.2 km in 4 h.

Cleaning of substrates was found in two of five lakes (Table 7.1) with the most vigorous activity noted on Michaud Lake, where noisy active cleaning and re-arranging of substrates occurred. In Whitepine Lake, cleaning activity also resulted in excavations of gravel substrate. In Lake Panache tight clusters of fish swam in inverted positions, behaviour not previously described. The actual spawning act was not directly observed.

The shallow nature of shoreline spawning sites appears to place sensitive early life stages in a highly vulnerable position relative to acidic run-off water, however it remains uncertain whether chronic or episodic chemical conditions cause recruitment failure. At Whitepine Lake, Gunn and Keller (1984) found that free embryos hatched from lake trout eggs incubated at site SS (Fig. 2.1) suffered only 18% mortality associated with pH depressions down to 4.5 and elevated levels of total Al up to 180 ug/l during spring snowmelt. Similarly, on Laundrie Lake, fresh fertilized eggs incubated overwinter at site C (Fig. 3.1) in 1985 and 1986 suffered only 38% mortality (mean value for 1985 and 1986) at pH = 5.6, total Al = 110 ug/l and inorganic monomeric Al = 22 ug/l (mean values for three week period during snow melt - G. Booth, Booth Aquatic Research, personal communication).

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APPENDIX 1 - Ultrasonic Tracking

Ultrasonic transmitter tags attached to adult lake trout proved to be effective for monitoring fish movements and for locating spawning sites. The use of transmitter tags is highly recommended over the traditional method of visual inspection of shorelines in lakes where few spawners exist or in lakes where little is known about spawning sites. This technology is particularly useful in cases, like Michaud Lake and Marina Lake, where fish spawned on sites sheltered from prevailing winds and where, without tags, time would have been wasted searching for sites along windswept shores. The spawning pair in Laundrie Lake would not have been found without the use of ultrasonic transmitter tags.

Ultrasonic tags are available from a number of suppliers (Vemco, Lotek, and Smith-Root) in various configurations of power output and pulse rate. Vemco (low power type V2B-2L) and Lotek tags (high output) were used in this study and are compared below:

Tag Type	Diameter (mm)	Length (mm)	Weight (gm)(1)	Freq. (khz)	Life (days)
Vemco	8	35	5.2	65.54 - 76.80	12
Lotek	10	40	14	74.00	28

(1) Both tags are nearly neutrally buoyant in water
Note: Pulse rates ranged from 50 to 80 beats per minute.

For a given tag size, increases in either power output or pulse rate shortens tag life. The penalty for longer tag life is an increase in tag size as extra battery cells are added. Although maximum tag size should be determined by the size of

fish, the size of water body and power output of the tag are important considerations. The Lotek tag, which has a higher output power than the Vemco unit, presented a problem with multiple echoes in the shallow waters encountered on Laundrie Lake. At close range, high power tags made it difficult to estimate the distance to the fish because the magnitude of the received signal did not vary appreciably with distance from the fish. More confusion would arise when two or more tags were present in the same area, especially when tag frequencies are not well spaced. For lake trout spawning work, the Vemco tag was a good compromise between power output and tag life and was well suited for smaller fish.

In this study, tags were fastened externally to fish by tying them alongside the dorsal fin with loops of stainless steel wire or monofilament line around the base of a fin ray at the anterior and posterior of the dorsal fin. Judging by the participation of tagged fish in spawning activity, the externally attached tags did not affect behaviour.

Surgical implantation of tags within the abdominal cavity is an alternative to external attachment of tags. Betteridge (1985) describes the procedure used in a study with rainbow trout (*Salmo gairdneri*) and splake (*Salvelinus fontinalis x S. namaycush*). Internally implanted tags have been actively expelled by channel catfish (*Ictalurus punctatus*) (Summerfelt and Mosier 1984) and rainbow trout (Chisholm and Hubert 1985) by the process of encapsulation within the intestine and passage through the anus.

Sonic tags were tracked using a CAI Model CR-40 receiver, with tuning range from 10 to 100 kilohertz (khz), in conjunction

with a V-10 directional hydrophone with a resonant frequency of 65 khz. The receiver worked well over a fairly wide range of temperature (-5 to 20 ^{o}C) and humidity (to supersaturation). The unit is ruggedly built and well sealed against the elements. There is provision for installing crystals for each frequency of operation rather than having to tune continuously. However, we found that frequency drift, presumably related to changes in temperature, hampered the use of crystal controlled channels. Also, the frequency read-out meter has poor resolution. Well spaced tag frequencies are desirable with any receiver and, if there are multiple tags close together in frequency, they should have different pulse rates.

Handling fish at any time, especially during a critical period like spawning, raises the question of what effect, if any, there is on fish behaviour. Our experience indicates a range of responses: on Whitepine Lake, fish resumed normal activity within 24 h of tag attachment while on Lake Panache five days passed before normal activity resumed. To provide a reasonable recovery time prior to oviposition, capture and tagging should be done as soon as fish are found on or near spawning sites.

APPENDIX 2. Lake trout tagged on Whitepine Lake - October, 1983.

Tag #	Date Caught	Site Caught (1)	Fork Length (cm)	Total Length (cm)	Weight (gm)	Sex	Clip (2)	Remarks
STOCKED FISH (N=26)								
260001	Oct 15	2	47.0	51.0	--	Male	AD	
260002	"	2	46.2	49.6	--	Male	AD	
260004	"	SS	50.8	56.2	1363	Male	NC	
260005	"	4	48.5	52.3	--	Male	AD	
260006	Oct 16	2	47.1	51.1	--	Male	AD	
260007	"	2	51.7	56.9	--	Male	NC	
260008	"	1	49.9	53.8	--	Male	AD	
260009	"	1	42.3	46.0	--	--	AD	
260010	"	1	44.2	47.9	--	--	AD	
260012	"	SS	45.2	48.8	--	Male	AD	
260014	"	1	47.9	52.3	--	Male	AD	
260016	Oct 18	4	44.5	48.2	--	Male	AD	
260017	"	2	47.2	51.1	--	Male	AD	
260018	"	2	46.6	50.5	--	--	AD	
260019	"	2	48.4	52.3	--	Male	AD	
260020	"	2	44.5	48.6	--	Male	AD	
260021	"	B	48.4	52.6	--	--	AD	
260022	Oct 22	C	46.7	50.5	--	Male	AD	
260024	"	D	43.8	47.8	--	Male	AD	
260025	"	D	46.3	50.2	--	Male	AD	
260026	"	D	46.0	51.0	--	Male	NC	
260027	"	D	46.2	50.5	--	Male	AD	
260028	"	D	43.5	46.7	--	Male	AD	
260029	Oct 26	D	46.8	50.6	--	Male	AD	Spent-previous tag lost
260030	Oct 30	C	43.4	48.2	--	Male	ADLP	Spent
NATIVES (n = 3)								
260003	"	B	55.8	60.9	--	Female	AD	
260011	Oct 16	SS	61.1	66.2	--	Male	AD	Tag torn loose Oct. 22
260015	Oct 16	SS	63.1	68.7	--	Male	NC	AD clipped during tagging

(1) See Fig. 2.1 for site locations
(2) AD - Adipose, LP - Left Pectoral, NC - No Clip

APPENDIX 3. Recaptures of Whitepine natives and Regan transplants previously tagged in 1982 or earlier.

Tag #	Date Caught	Site Caught	Fork Length (cm)	Total Length (cm)	Weight (gm)	Sex	Clip[1]	Origin[2]	Remarks
A73501	Oct 15	1	59.8	62.3	--	Male	AD	WP	Sonic tag 'A'
A73502	Oct 15	1	62.0	67.5	--	Male	AD	WP	
A73516	Oct 16	2	46.5	51.5	* 1125	Female	NC	R6	Sonic tag 'B'
A73504	Oct 18	2	----	----	--	Male	AD	WP	Freely flowing
A73506	Oct 22	D	* 54.3	* 59.7	* 1650	Female	NC	R6	Sonic tag 'C'
A73514	Oct 26	D	* 61.5	* 62.5	* 2950	Female	NC	R6	Spent
260000	Oct 15	2	54.3	60.1	--	Male	NC	R6[3]	
260013	Oct 16	SS	45.5	50.0	1095	Male	NC	R6[3]	
260023	Oct 22	C	61.0	65.0	--	Male	AD	WP[3]	

(1) AD - Adipose, LP - Left Pectoral, NC - No Clip
(2) WP - Whitepine native, R6 - Regan transplant
(3) 1982 tags lost, retagged with 1983 series
* Data collected in 1982

APPENDIX 4 (a). Summary of temperature (°C) and dissolved oxygen (D.O.in (mg/l) at spawning site - Michaud Lake, October 13-18,1984.

Date	Oct. 13	Oct. 14	Oct. 15	Oct. 16	Oct. 17	Oct. 18
Temp.	11.7	11.7	11.4	11.4	11.2	11.1
D.O.	9.7	9.6	9.5	9.3	9.8	9.4

APPENDIX 4 (b). Mid-lake temperature (°C) and dissolved oxygen (D.O. in mg/l) profiles - Michaud Lake, October, 1984. Station depth 23 m.

Date	October 11		October 13		October 15		October 17	
Depth(m)	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
0	11.8	9.2	11.9	9.9	12.0	10.3	11.9	9.9
1	11.0	9.2	11.9	9.9	12.0	10.4	11.9	9.9
2	11.0	9.1	11.5	9.9	11.8	10.3	11.9	10.0
3	11.0	9.2	11.2	9.9	11.6	10.3	11.9	9.9
4	11.0	9.1	11.2	9.8	11.4	10.2	11.8	9.9
5	11.0	9.1	11.1	9.7	11.1	10.2	11.7	9.9
6	11.0	9.1	11.0	9.7	11.0	10.0	11.7	9.9
7	11.0	9.0	10.9	9.6	11.0	10.0	11.7	9.8
8	11.0	9.1	10.9	9.6	11.0	9.9	11.5	9.8
9	11.0	9.0	10.9	9.6	11.0	9.8	11.0	9.6
10	10.9	8.9	10.8	9.5	10.9	9.8	11.0	9.4
11	10.5	8.6	10.5	9.3	10.2	9.5	10.8	9.3
12	7.9	5.8	8.4	6.9	7.9	6.4	8.2	6.8
13	6.5	5.5	7.5	6.1	6.8	6.1	7.0	6.1
14	6.2	5.4	6.6	5.9	6.2	6.0	6.2	5.6
15	6.0	5.1	6.2	5.4	6.0	5.8	---	---
16	5.9	4.6	6.0	5.1	6.0	5.0	6.0	4.7
17	5.8	4.4	5.9	4.2	5.8	4.7	---	---
18	5.6	4.0	5.7	3.5	5.6	4.3	5.8	3.9
19	5.4	3.5	5.6	3.1	5.5	3.9	---	---
20	5.4	2.7	5.5	2.4	5.5	3.6	5.5	3.4
21	5.2	2.1	5.4	1.8	5.4	2.5	---	---
22	5.1	1.0	5.4	1.4	5.2	1.5	5.1	2.1
23	5.1	0.8	---	---	---	---	---	---

APPENDIX 4(c). Weather summary - Michaud Lake, October 10-17, 1984.

Date	Time	Air Temp. (°C)	Remarks
10	*1936	--	Calm, clear skies, slight haze
11	1210	19.0	Calm, clear skies
	*1929	--	Calm, clear skies, warm
12	*2000	--	Calm, 10% cloud, warm
13	0830	5.0	Calm, mist on water
	1200	--	SW breeze (slight), 100% overcast, warm
	1417	14.3	SW wind (moderate), 30% cloud
	*1912	--	SW breeze (slight)
14	0930	--	Calm, foggy
	1000	14.3	Calm, clear skies
	1405	--	Calm, slight high overcast, warm
	*1821	--	Calm, slight overcast, warm
	*2142	--	Calm
15	0948	7.5	---
	1200	16.0	E breeze (slight), clear skies
	*1907	--	Calm, clear skies, warm
16	0800	--	Calm, clear skies, warm, no sign of frost
	1025	9.8	SSE breeze, clear skies
	*1915	--	Calm, clear skies, warm
17	0800	--	SE wind, 100% overcast, warm
	1019	10.5	SE wind (moderate), overcast
	1200	12.0	SE wind (moderate), 100% overcast, raining
	*1920	--	Calm, clear skies, mist on water
	*2145	--	Calm, foggy

* - Conditions during evening spawning observations

APPENDIX 5. Summary of mid-lake temperature (°C) and dissolved oxygen (mg/l) profiles - Marina Lake, October, 1985. Station depth 15 m.

Date	October 16		October 18		October 20		October 22	
Depth (m)	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
0	9.2	9.8	9.0	10.5	9.3	10.0	8.2	10.9
1	9.2	9.7	9.0	10.5	9.0	9.9	8.3	10.8
2	9.2	9.7	9.0	10.5	8.8	9.9	8.3	10.8
3	9.2	9.7	9.0	10.5	8.7	9.9	8.3	10.8
4	9.2	9.7	8.9	10.5	8.7	9.9	8.3	10.8
5	9.2	9.7	8.9	10.5	8.6	9.8	8.3	10.8
6	9.2	9.7	8.9	10.4	8.5	9.8	8.3	10.8
7	9.2	9.7	8.9	10.5	8.5	9.7	8.3	10.8
8	9.2	9.7	8.9	10.5	8.5	9.7	8.3	10.8
9	9.2	9.7	8.9	10.5	8.5	9.8	8.3	10.8
10	9.2	9.6	8.9	10.3	8.4	9.6	8.2	10.7
11	9.1	9.6	8.8	10.3	8.3	9.6	8.2	10.7
12	8.7	9.1	8.3	9.5	8.1	9.2	8.0	10.3
13	6.0	4.7	7.7	7.8	6.9	5.4	7.0	8.9
14	5.5	2.6	5.8	3.4	5.5	2.2	6.0	3.3
15	---	---	5.3	1.3	---	---	5.5	0.7

Date	October 24		October 26		October 28		October 30	
Depth (m.)	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
0	9.0	9.2	8.2	10.4	7.5	10.2	6.9	10.1
1	9.0	9.2	8.2	10.4	7.5	10.1	6.9	10.0
2	9.0	9.2	8.2	10.4	7.5	10.1	6.9	10.0
3	9.0	9.2	8.2	10.4	7.5	10.1	7.0	10.0
4	9.0	9.1	8.2	10.4	7.5	10.1	7.0	9.9
5	9.0	9.1	8.1	10.4	7.5	10.1	7.0	9.9
6	8.9	9.1	8.1	10.3	7.5	10.1	7.0	9.9
7	8.9	9.0	8.1	10.3	7.5	10.1	7.0	9.9
8	8.5	8.9	8.1	10.4	7.5	10.1	7.0	9.9
9	8.2	8.8	8.1	10.3	7.5	10.1	7.0	9.9
10	8.2	8.7	8.1	10.3	7.4	10.1	7.0	9.9
11	8.1	8.6	8.0	10.3	7.4	10.1	7.0	9.9
12	8.0	8.4	8.0	9.7	7.4	10.1	7.0	9.9
13	7.6	6.8	8.0	6.3	7.4	10.1	6.9	9.8
14	5.9	1.6	6.3	3.5	7.4	10.1	6.9	9.8
15	5.3	0.3	5.8	1.5	7.2	10.1	6.9	9.8

Appendix 6. Summary of water temperature (Temp.) and dissolved oxygen (D.O.) profiles for the north central basin of Lake Panache - October 1984.

	DATE							
	October 16		October 18		October 21		October 29	
Depth (m)	Temp. (°C)	D.O. (mg/l)	Temp. (°C)	D.O. (mg/l)	Temp. (°C)	D.O. (mg/l)	Temp. (°C)	D.O. (mg/l)
0	12.6	-	13.4	10.0	12.3	9.4	11.4	9.4
1	12.6	-	13.3	10.0	12.3	9.2	11.4	9.3
2	12.6	-	13.3	10.0	12.3	9.2	11.4	9.3
3	12.5	-	13.3	9.9	12.3	9.2	11.4	9.3
4	12.4	-	13.3	9.9	12.3	9.2	11.4	9.2
5	12.4	-	13.3	9.9	12.3	9.1	11.4	9.2
6	12.3	-	13.3	9.9	12.3	9.1	11.4	9.2
7	12.2	-	13.3	9.9	12.3	9.1	11.4	9.2
8	12.1	-	13.2	9.9	12.3	9.1	11.4	9.2
9	12.1	-	13.2	9.8	12.3	9.1	11.4	9.2
10	12.0	-	13.2	9.8	12.3	9.1	11.4	9.2
11	12.0	-	13.1	9.8	12.3	9.1	11.4	9.2
12	12.0	-	13.1	9.8	12.3	9.1	11.4	9.2
13	11.7	-	13.1	9.8	--	--	11.4	9.2
14	11.5	-	13.0	9.6	12.3	9.1	11.4	9.2
15	10.9	-	12.8	9.4	--	--	--	--
16	10.5	-	12.4	7.0	11.1	7.5	11.4	9.1
17	9.7	-	11.0	6.8	--	--	--	--
18	9.1	-	10.4	6.7	10.5	6.9	11.4	9.1
19	9.0	-	10.2	6.6	--	--	--	--
20	8.8	-	10.1	6.5	10.3	6.6	11.4	9.1
21	8.7	-	9.9	6.4	--	--	--	--
22	8.7	-	9.8	6.3	10.3	6.5	11.4	9.1
23	8.6	-	9.8	6.2	--	--	--	--
24	8.5	-	9.8	6.0	10.0	6.4	11.4	9.0
25	8.5	-	9.8	6.0	--	--		
26	8.5	-	9.7	6.0	10.0	6.3		
27	8.5	-	9.7	5.9	--	--		
28	8.4	-	9.7	5.9	9.9	6.2		
29	8.4	-	9.7	5.9	--	--		
30	8.3	-	9.7	5.9	9.9	6.1		

Note: The water temperatures in the upper strata (0 - 16 m) on the 18th were likely elevated by an air mass which brought strong winds and warmer air temperatures on the evening of the 17th and prevailed on the 18th.